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IMPLEMENTATION OF DOP REPLACEMENT WITH SELECTED MATERIALS IN MASK AND FILTER TESTING PENETROMETER MACHINES: FINAL REPORT

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RESEARCH DIRECTORATE

June 1992

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13. ABSTRACT (Maximum 200 words)
In April 1986, the U.S. Army's Office of the Surgeon General (OTSG) took the position that dioctyl phthalate (DOP) is a suspected carcinogen. The U.S. Army had used DOP for many decades for nondestructive serviceability testing of respirator canisters and protective filters and in a variety of aerosol penetration studies including mask leakage and face fit. The present program to find a safe material was initiated in September 1987, under sponsorship by the Product Assurance Directorate (PAD). A synthetic lubricant, Emery 3004, from the class of compounds called poly-alpha olefins has been selected from the 36 promising materials, which have inherently low toxicities, that were studied. It was approved by the OTSG on January 8, 1992 for use Army-wide as a safe replacement for DOP in "hot smoke" and "cold smoke" testing in a variety of machines after successfully passing three tiers of mutagenic testing. It performs at least as well as DOP in hot smoke machines that generate near-monodispersed test aerosols. It can replace DOP directly in existing penetrometer and other machines without machine modification. It is inexpensive, readily available, readily specifiable, noncorrosive, free of natural impurities, and thermally and chemically stable. It is recommended that Emery 3004 be implemented to replace DOP in Army-wide testing as soon as it is practicable.

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TDA-100	

PREFACE

The work described in this report was authorized under Engineering Study Proposal (ESP) No. FI-7-8860, "Alternative for DOP," and was completed using OMA funds in-house Project No. FI-7-8860. This work was started in September 1987 and completed in February 1992.

The use of trade names or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

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The authors express their sincere appreciation to Bernard V. Gerber for his consultative services to this program in its initial stages. His expertise in the aerosol sciences, combined with his timely insights in the execution of this research, did much to insure its successful outcome.

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IMPLEMENTATION OF DOP REPLACEMENT WITH SELECTED MATERIALS IN MASK AND FILTER TESTING PENETROMETER MACHINES: FINAL REPORT

1. INTRODUCTION

1.1 Background.

Di (2-ethylhexyl) phthalate, also called dioctyl phthalate, di-sec octyl phthalate, DOP, or DEHP, is a widely used industrial material. Over ninety percent of the material produced is used as a plasticizer, primarily for PVC plastics. The properties of DOP that make it useful as a plasticizer, including low vapor pressure, chemical stability, and insolubility in water, also make it useful as a test aerosol. DOP aerosols are used in respirator fit testing, HEPA filter testing, aerosol research, aerosol instrument calibration, and other applications. These uses involve human occupational exposure to submicrometer-sized DOP aerosols, often briefly but in moderately high concentrations.[1]

Concern about the potential health effects to people working with DOP test aerosols has led to a search for substitute materials.[1] This search has taken a number of different directions, depending in part upon the specific test applications for which a DOP replacement has been sought. For example, Hinds, et al,[2] looked at size distributions of test aerosols of corn oil, di (2-ethylhexyl) sebacate (DOS), mineral oil, and polyethylene glycol (PEG), and compared these to DOP. Gerber[3] has published a detailed study of glycols as safe DOP replacements. Other comparative studies of size distribution and filter penetration of corn oil,[4] mineral oil, PEG, and DOP have been reported.[5] Interest has been revived in the use of solid aerosols including salts as test media,[6] and in their performance compared to DOP aerosols.

The U.S. Army routinely performs 100% quality control testing of filter canisters manufactured for use with field-issue gas masks, and periodic sampling and testing of canisters stored in its supply depots. In April, 1986, the U.S. Army Surgeon General placed severe restrictions upon testing with DOP; agencies were also informed that dioctyl sebacate (DOS) would no longer be acceptable as a DOP replacement material, and that similar restrictions would apply for both. These restrictions included occupational exposure monitoring of workers exposed to DOP aerosols and liquid, medical surveillance, issue of personal protective equipment, formal notification to workers of associated risks, and labeling of work areas as "cancer suspect agent areas."

1.2 Study of Candidate Replacement Materials for DOP.

Clearly, the above actions placed severe restrictions upon routine, 100% quality assurance testing of filters and other equipment. For this reason, in 1988 the U.S. Army initiated a detailed study of the problem

of finding an acceptable substitute material for DOP that could meet all standard military test specifications while itself being a non-carcinogen and, ideally, having other attributes including acceptable acute inhalation toxicity, low cost, ready availability, and the ability to replace DOP directly in machines at test installations without retrofit or other modification of these machines.

A report was published[7] describing the experimental procedures and results of that study which are applicable primarily to "hot smoke" aerosol penetrometer machines including the Army-standard "Q-127" machine that is currently produced as the Model TDA-100 by Air Techniques, Inc. (ATI).[8] Several dozen samples of promising materials were obtained and tested in two filter-penetrometer machines: (1) a standard Q-127 "hot smoke" machine, and (2) the Los Alamos Monodispersed Aerosol Prototype Penetrometer (LAMAPP), a state-of-the-art developmental machine that produces smokes from liquids at room temperature. Based on this research and subsequent testing, prime candidate replacement materials for DOP were selected.

1.3 Selection of Prime Candidate Replacement Material(s).

The report[7] identifies several materials that are now the prime candidates to replace DOP in "hot smoke" penetrometer machines such as the Q-127/TDA-100, and in "cold pot" machines like LAMAPP. These are summarized in Table 1, with sources of supply.[9] The materials identified here as DOP alternatives or replacements are generally inexpensive, and readily available. Their detailed Material Safety Data Sheets (MSDS) are presented here in Appendix A.

Synthetic hydrocarbons include poly-alpha olefins (PAOs), which are used as synthetic lubricants, and in other applications. These versatile, saturated, synthetic hydrocarbons are produced by direct oligomerization of decene-1. Linear alpha olefins are polymerized and hydrogenated to manufacture PAOs. Three PAOs were investigated in our studies; these are designated Emery 3002, 3004 and 3006. Data are summarized in Table 2.

Isostearic acid has the structural formula:

$$CH_3\text{-}\overset{\displaystyle CH_3}{\overset{/}{C}H}\text{-}(CH_2)_{14}\text{-}COOH \qquad (1)$$

where the single branched methyl group usually occurs in the position shown but also can occur at any other position along the carbon chain with a much lower probability. Thus it is an isomer of stearic acid, but the two acids have distinctly different physical properties. Isostearic acid is a light yellow liquid at room temperature with a melting point of 12-15°C, depending upon its purity, and it has a vapor pressure of 50 mm Hg at 265°C. Its flash point is approximately 182°C, open cup.

Two samples of differing purity were used in this work. The purest sample was 70-76% isostearic acid, with the remainder consisting of myristic, isopalmitic, and palmitic acids, in that order. The less pure sample was 60-66% isostearic acid, with the remainder consisting of isooleic, oleic, stearic, and isopalmitic acids, in that order.

Table 1. Recommended Replacement Materials for DOP in Q-127 and TDA-100 Machines, and in the LAMAPP Machine, Ranked in Order of Probable Success.

	Q-127 and TDA-100 Machines		LAMAPP Machine	
Ranking*	Chemical Name	Manufacturer[9] or Source	Chemical Name	Manufacturer[9] or Source
1	synthetic hydrocarbon Emery 3004	Emery Group Henkel Corp..	synthetic hydrocarbon Emery 3002	Emery Group Henkel Corp.
2	isostearic acid (76%) Emersol 875	Emery Group Henkel Corp.	isostearic acid (76%) Emersol 875	Emery Group Henkel Corp.
3	isostearic acid (66%) Emersol 871	Emery Group Henkel Corp.	methyl oleate stearate Emery 2219	Emery Group Henkel Corp.
4	synthetic hydrocarbon Emery 3006	Emery Group Henkel Corp.	synthetic hydrocarbon Emery 3004	Emery Group Henkel Corp.
5	oleic acid (71%) Industrene 206LP	Humko Chem. Div., Witco Chem. Corp.		
6	oleic acid (74%) Emersol 233LL	Emery Group Henkel Corp.		

* Highest rankings have highest probability of success.

Table 2. Properties of Poly-Alpha Olefins (PAOs).

Trade Name	Pour Point, °C	Flash Point, °C	Fire Point, °C	Auto-Ignition Point, °C	Specific Gravity
Emery 3002	-65	164	178	324	0.80
Emery 3004	-69	225	250	343	0.82
Emery 3006	-64	243	266	371	0.83

See Ref. 9

Oleic acid has the structural formula:

$$CH_3\text{-}(CH_2)_7\text{-}CH\text{=}CH\text{-}(CH_2)_7\text{-}COOH \tag{2}$$

where one double bond exists between the ninth and tenth carbons of an 18-carbon chain. The molecule is most easily chemically attacked at this double bond, making this acid less stable during aging at elevated temperatures than saturated fatty acids. Nevertheless, it performs well in the Q-127 machine with the exception that the aerosol concentration is so great that is is sometimes difficult to control. Oleic acid is not recommended for use in the LAMAPP machine.

The oleic acid used here was 71-74% pure, with the remainder consisting mainly of palmitoleic and linoleic acids, in that order. It is a light yellow liquid at room temperature, with a slight odor. It melts at 11-14°C, and has a vapor pressure of 10 mm Hg at 224°C. Its flash point is approximately 184-189°C closed cup, and 193°C open cup.

Methyl oleate stearate is a mixture of 58% methyl oleate, whose structural formula is:

$$CH_3\text{-}(CH_2)_7\text{-}CH\text{=}CH\text{-}(CH_2)_7\text{-}COO\text{-}CH_3\ , \tag{3}$$

24% methyl stearate, whose structural formula (where n = 18) is:

$$CH_3\text{-}(CH_2)_{n-2}\text{-}COO\text{-}CH_3 \tag{4}$$

14% methyl linoleate, and 4% methyl palmitate (n = 16 in the formula above). It melts at 18°C, and is a light yellow liquid. Its vapor pressure is 10 mm Hg at 205°C, and its flash point is approximately 173°C open cup.

1.4 Plan for DOP Replacement with Selected Material(s).

Our primary mission in this program was to identify a safe replacement material for hot smoke machines including Q-127/TDA-100s that could be used to replace DOP directly in existing machines with a minimum of downtime and/or machine modification. That best material (Emery 3004) would then have to pass toxicological screening so as to, ultimately, obtain approval by the U.S. Army Surgeon General for use Army-wide. The prime candidate materials might also find application not only in "cold pot" machines like the LAMAPP, but in a wide variety of other "cold smoke" machines used routinely for respirator seal leakage testing and other quality control applications. Accordingly a plan was developed for the implementation of DOP replacement with the prime candidate material(s) in mask- and filter-testing machines. The plan included the following elements:

- study the thermal stability ("aging") of the material(s) for "hot pot" machine applications, and other relevant physical properties;

- study the toxicological and carcinogenic properties of the material(s) to obtain documentation required by the U.S. Army Surgeon General to consider approval for their use in testing Army-wide;

- engage in collaborative studies to evaluate the material(s) with Product Assurance Directorate (PAD, the sponsors of this program), and with any other interested U.S. Government organizations and/or penetrometer test equipment manufacturers;

- offer consultative assistance on DOP replacement to interested organizations including those within the U.S. Government and the private sector;

- disseminate our results and obtain feedback through technical presentations at national and international meetings, and through publication in reports, conference proceedings, and research papers in the open literature;

- secure U.S. Patent protection against the payment of royalties by the U.S. Government for the use of DOP replacement materials and/or technology;

- ultimately, obtain final approval for the use of the prime DOP replacement material from the U.S. Army Surgeon General

2. IMPLEMENTATION OF DOP REPLACEMENT

2.1 Studies of Selected Material(s).

When DOP, and candidate materials being investigated to replace DOP, are used in test equipment they are subjected to a variety of operating conditions. Particularly in "hot smoke" machines, where these materials are held in reservoirs ("hot pots") operated at temperatures near 200 °C for periods of time ranging from days to weeks, thermal "aging" or discoloration, polymerization, and other chemical changes can occur. DOP itself is observed to change from a colorless liquid to a honey-colored or deeper brown one during prolonged use at elevated temperatures.

Thus, it is important that the thermal and other physical properties of replacement materials are not markedly worse than, and hopefully are better than, those of DOP in such applications.

In other applications, such as "cold smoke" testing of mask fit, heating of the material is not required and hence thermal properties are less important. But oxidation, due to air used to generate aerosol sprays from nozzles, can be troublesome here. While DOP can withstand contact with oxygen without serious adverse effects, materials such as corn oil cannot; the latter deteriorates to cause gumming and plugging of equipment in which it is used.

Ultimately, of course, any material selected to replace DOP due to the suspected carcinogenicity of that material must not itself exhibit carcinogenic tendencies or unacceptable toxicity. The entire research program discussed here is motivated by this consideration. Thus, a successful DOP replacement material must not only demonstrate by testing that it can withstand the rigors of hot or cold machine operation, but that in normal use it does not pose hazards of its own to humans in the machine environment.

The U.S. Army requires these test smokes (aerosols) to meet these specifications:

- The geometric mean diameter (GMD), in micrometers (um), of the aerosol must lie between 0.18)m and 0.33 um. This is the count or number mean of the distribution. That is, all particles in all size ranges are counted, and a distribution is drawn showing the total number of particles in all ranges (a histogram). From this, a mean size is determined.

- The geometric standard deviation (GSD) of the distribution must not exceed 1.30. The GSD is a measure of the narrowness (width) or "monodispersity" of the particle size distribution. An aerosol of particles of all one size would have a GSD = 1.00. This is impossible to achieve even with latex spheres that are used to calibrate the instruments. The specified upper limit of GSD = 1.30 insures that the width of the distribution is adequately narrow for desired tests. By comparison, aerosols produced by spraying (without vaporization and recondensation) often have GSDs of 2.00 or more.

- The smoke concentration at the test chuck where filter canisters are inserted must be 100 mg/m^3 plus or minus 20 mg/m^3 for the TDA-100 (Q-127) machine, and 20 mg/m^3 plus or minus 10 mg/m^3 for the LAMAPP.

2.1.1 Thermal Stability and Other Physical Properties.

When DOP and candidate replacement materials are operated for hundreds of hours in heated reservoirs ("hot pots") such as those used in hot smoke machines like the TDA-100 (Q127), chemical changes can occur in the materials as well as changes in other physical properties. These could affect the performance of a material in producing test smokes to specification or, worse, could lead to the formation of breakdown products that were themselves toxic or carcinogenic. Thus, laboratory analyses are required at periodic intervals during testing of candidate materials in "hot" machines to monitor any significant changes. These analyses comprise what are called "aging" studies.

In February of 1990, samples of Emersol 875 isostearic acid that had been "aged" for 6, 24, 36, and 84 hours in a Q127 hot pot operating at a temperature near 170 ^{0}C were analyzed by mass spectroscopy (MS) and nuclear magnetic resonance (NMR). These were compared to a sample of the neat, fresh material, which was found to be 98.9% pure acid. Metal ion complexes were detected in the aged samples due to contact of the material with iron and copper components in the machine hot pot. These did not affect the performance of the material to produce test smokes, but did produce a greenish to black discoloration with increasing aging time.

Samples of Emery 3004 poly-alpha olefin (PAO) that were run in the Q127 hot pot also were analyzed by NMR. The aging times were 0 (new material), 1, 16, 30, 47, and 87 hours. The spectra appeared to be identical for all samples. No evidence of metal ions was found, probably due to the fact that PAOs are chemically neutral, unlike isostearic acid. A sludge had begun to form in the two longest-aged samples, but solvent extraction and separate spectral analysis of the sludge showed no differences from the neat material.

In April of 1990, a further series of analyses was undertaken by the Analytical Research Division, CRDEC, in which fresh and aged samples of DOP and Emery 3004 that had been run in new TDA-100 (Q127) machines at 160-170 °C for up to 110 hours were compared.

The DOP samples were taken fresh (no aging) and at 100 hours. The Emery 3004 samples were taken fresh, and at 16, 32, 80, and 110 hours. All samples were analyzed by gas chromatography/mass spectrometry (GC/MS) for changes with aging. The DOP samples and the fresh and 110-hour Emery 3004 samples were also analyzed by inductively coupled plasma (ICP) emission spectrometry for the presence of iron and copper and/or changes due to oxidation, and by infrared (IR) spectroscopy for any gross differences due to long-term heating effects.

Results indicated that the fresh and aged DOP samples were essentially identical although the color had changed from clear to honey-brown. The Emery 3004 samples were similar also, with the 110-hour one showing a weak indication of a possible C=O moiety. Color change was very similar to that for DOP aged 100 hours. The aged DOP contained a trace of didecyl phthalate.

The Emery 3004 samples were essentially as reported, a mix of C_{20}, C_{30}, and C_{40} polyolefins with molecular weights (MW) of 280, 420, and 560, respectively. The aged samples showed a trace of a C_{30} aldehyde, probably indicative of slight thermal decomposition by oxidative pyrolysis.

Because PAOs, including Emery 3004, are produced by combining 10-carbon decene molecules, the resulting products do not contain distributions of sequential carbon chain lengths, like those found in common petroleum products, which are difficult to separate by distillation. Instead, each PAO consists of chain lengths in multiples of 10 which, in principle, should allow easier distillation to obtain samples of a single kind of molecule of high purity. Approximate analyses for several Emery PAOs as given by their manufacturer are listed in Table 3. The last figure of the "3000" series of numbers indicates the viscosity in centistokes of that particular mixture at 100 °C.

Table 3. Approximate Analyses by Carbon Chain Length for Several Emery[9] Poly-Alpha Olefins (PAOs).

Emery[9] Product	Percentages by Carbon Chain Length					
	C20	C30	C40	C50	C60	C70
3002	97-99	1.0				
3004	0.60	82.1	16.0	1.0	2.0	
3006		30.9	42.8	20.4	4.8	1.1

The molecules comprising the PAOs become progressively non-linear with increasing size. Thus, for larger sizes, the molecules increasingly become isomers of one another. The manufacturing process begins with decene-1, a linear hydrocarbon molecule of 10 carbons with one double bond at the first position. The decene-1 is polymerized in the presence of a BF_3 catalyst, hydrogenated to saturate any remaining double bonds, and distilled into fractions (dimer C_{20}, trimer C_{30}, quatrimer C_{40}, ...). These are blended to produce desired product mixtures for various applications.

The manufacturer indicates that the C_{20} dimer is nearly straight-chained but, because polymerization occurs at the site of the decene-1 double bond, a "bending" occurs such that the dimer molecule has the form:

```
          C
         /
C7 - C - C - C - C8                (5)
             /
            C
```

Structural theories of the PAOs suggest that as the molecules become larger chain attachment occurs at selected sites such that the C_{30} trimer has the form:

```
          C
         /
C7 - C - C - C - C8                (6)
        /   /
  C - C    C
     /
   C8
```

while the C_{40} quatrimer has a form resembling:

```
             C
            /
     C7 - C - C - C - C8           (7)
            /   /
C8 - C - C     C
    /   /
   C   C - C
      /
    C7
```

Materials other than decene-1 can be used to make PAOs, but decene-1 gives products with the most desirable range of viscosities for lubricants. To prevent discoloration due to oxidation catalyzed by contact with metals during use, antioxidants can be added to PAOs in concentrations well below one percent.

2.1.2 Toxicology and Carcinogenicity.

Our primary candidate to replace DOP in most hot and cold testing applications is the poly-alpha olefin (PAO), "Emery 3004." Some properties and other facts concerning PAOs like Emery 3004 are discussed in Appendix B.

Very recently manufacturers of PAOs[9] including Emery 3004 have reissued MSDSs, as required by law when previously unknown but pertinent information becomes available, to reflect the 1982 findings of Guiney[10] on the acute toxicity assessment of PAOs (see Appendix A).

The new Emery MSDS for PAOs claim that although the toxicities estimated in Guiney's study were significant, the test conditions were such that the test animals (rats) were subjected to great physical insults, sufficient that observed histopathical changes may have been a response to these insults rather than being related to a specific compound toxicity effect. The MSDS indicate that PAOs may be considered non-hazardous, for all practical purposes, by inhalation. Indeed all oils, including the purest of mineral oils, are capable of causing "oil pneumonia" and/or death by suffocation when inhaled at very high aerosol concentrations for periods of more than several minutes. Since oils cannot be cleansed easily from the lungs due to their extreme hydrophobicity, and a build-up and coating of the lung surfaces is inevitable. Humans and animals subjected to such physiological insults respond by coughing, and by exiting the contaminated area. A confined test animal, on the other hand, would be subjected to great physical and psychological trauma in the presence of very high, suffocating oil aerosol concentrations, and could succumb rapidly for a variety of reasons.

To investigate the exact nature of conditions to which the test rats were subjected, visual and other data observations from Guiney's paper were analyzed using optical constants from a paper[11] containing optical extinction (i.e., attenuation) coefficients at wavelengths including the visible, for oil smokes and aerosols. From the extinction coefficients, the actual oil aerosol concentrations to which the rats were subjected were calculated. The test visibility conditions were such that the heads of the rats confined in test chambers could be seen under normal lighting conditions, but their hind quarters could not. This would be roughly equivalent to subjecting oneself to an oil aerosol or "fog" so thick that one could not see a hand six inches in front of his or her face. The aerosol mass concentration was estimated at 5,000 mg/m^3 (5 g/m^3), or roughly 1,000 times the PEL or TLV values normally given as safe for occupational exposure limits for oil mists.

In summary, it would appear that the test conditions under which PAOs were considered to be potentially toxic by inhalation were completely unlike those reasonably expected to be found in actual experience. The acute toxicities of the PAOs are comparable to that of DOP.

A study of the possible carcinogenicity of Emery 3004 was begun during 1990. Samples of this material were subjected to an Ames Assay, as a preliminary screening precedure, with negative results.

More correctly, the Ames assay system measures the mutagenicity of a material. A memorandum from Fred K. Lee, Jr., of the CRDEC Research Directorate's Biosciences Branch, Toxicology Division, dated 22 August 1990, contained the following information. Its subject was the mutagenicity testing of Emery 3004 (see Section 3.2, below).

The compound Emery 3004 was tested by Toxicology Division, CRDEC, for mutagenic potential in the Ames system and was found to be negative. The compound as supplied, a clear viscous liquid resembling mineral oil, was emulsified in 1% Triton X 100 in distilled water at a concentration of 100,000 ug/mL and tested at concentrations of 1, 10, 100, 1000 and 10,000 ug per petri plate.

The negative control, 1% Triton X 100 in distilled water, was also used in preparing the dilutions for testing. The four standard Ames strains (TA97, TA98, TA100 and TA102) were used in the plate incorporation assay. Testing was done both with and without metabolic activation using arochlor 1254 induced rat liver S9.

Although the Ames Test is currently perceived as the backbone of mutagenicity testing, it should not be used independently in estimating human risk factors. However, if one uses the results of a carefully selected battery of test protocols, human risk assessment becomes feasible. Toxicology's tier approach to mutagenicity is the recommended approach to mutagenicity testing. Two additional stages or tiers of testing were carried out as part of our FY1991 program, as outlined in Section 3.2.

2.2 Collaborative Studies.

2.2.1 Testing with Other Government Organizations.

2.2.1.1 Product Assurance Directorate (PAD).

PAD was the sponsor of the CRDEC Research Directorate's DOP Replacement Program from its inception in September 1987 under Engineering Study Proposal (ESP) No. FI-7-8860, "Alternative for DOP." As an ultimate user of any successful replacement material for DOP in quality control testing of U.S. Army materiel, PAD has maintained close contact with Research Directorate technical personnel both administratively, through monthly progress reports submitted to them, and by joint participation in testing using candidate materials in their machines. Some examples of these efforts are discussed in this section.

PAD maintains several kinds of filter test machines in the Edgewood Area (EA) of Aberdeen Proving Ground (APG), MD. These are of both the hot smoke and cold smoke varieties. They include the Q-127, Q-233, formerly the Q-76, and the Q-107, which is the largest of the hot smoke filter test machines. These machines are manufactured, under current model numbers, by Air Techniques Inc.(ATI)[8], Baltimore, MD 21207.

Each of these machines operates on the vaporization/recondensation principle of smoke generation. Heated vapor pickup air is passed over a heated pot of DOP or other material. The heated, vapor-rich air then mixes with

cooler quench air, producing a controlled recondensation process. The Q-127 (TDA-100, Appendix G) uses this process to generate test smokes at modest flowrates to test small gas mask canister filters.

The Q-233 and Q-107 machines operate at much higher flowrates. These machines, compared with the Q-127, use different temperatures, hot pot sizes, and airstream flowrates, plus an additional "make-up airstream." After recondensation of the vapor or other smoke material, its flow is mixed with the make-up airstreamto bring the final test airstream to its required volume.

Unlike the Q-127, there are few Q-233 and Q-107 filter test machines available for conducting DOP replacement research. PAD currently has one each of these machines, but would not allow testing of candidate replacement materials owing to possible contamination problems. Our tests were limited to the updated CRDEC Q-127 machine. Thus, we must assume that DOP and candidate material performances, in machines other than the Q-127, would be similar.

DOP smoke was generated in PAD's Q-233 machine, and was characterized using a laser aerosol spectrometer ("LAS-X"), in the same manner as with our Q-127 machine.[7] The DOP smoke was generated under standard instrument operating conditions by PAD personnel, and was sampled just downstream of the mechanical "Owl"[7] to permit silmultaneous Owl and LAS-X particle size determinations to be made. The LAS-X smoke stream was diluted, typically by a factor of 2,000, through two TSI model 3302 aerosol diluters in series, prior to introduction to the instrument.

Standard DOP smokes generated by the Q-233 have air flows of 20 SCFM or 100 SCFM depending on the size of filters being tested. To achieve the minimum 100 mg/m^3 test smoke concentration, the hot pot temperature is maintained at 195^oC. Vapor pickup air and quench air are set to produce a total flowrate of 20 SCFM. When a 100 SCFM total flowrate is required, the makeup airstream is added proportionately. Since the pot temperature is not altered for either flowrate, the mass concentration of smoke is much larger at 20 SCFM than the minimum 100 mg/m^3 at 100 SCFM.

Flowrates of the Q-233 are monitored as pressure differential readings instead of by actual flowmeters. Aerosol particle size is controlled by changing the temperature of the quench airstream, as with the Q-127. Typical test conditions and LAS-X data are presented in <u>Appendix H</u>

Mean particle sizes of the DOP smokes produced by the Q-233 were found to be in the expected size range, 0.19-0.26 um, for an Owl reading[7] of 29 degrees. This size range is consistent with our findings for DOP generated in Q-127 machires. The geometric standard deviation ("sigma g") of DOP smokes from the Q-233 was found to be larger than for those from the Q-127, with Q-233 values consistently being in the 1.40-1.44 range. This range exceeds the limit of 1.3 established for smokes from hot smoke machines.

PAD engineers concluded that the broader distribution was inherent in the larger smoke machines, and therefore that the limit or ceiling of 1.3 should apply only to smokes produced in the Q-127 and LAMAPP[7] machines.

PAD also maintains several types of cold smoke machines used in respirator fit testing. In fit testing, respirator components such as eye

lens mounts and filter cartridge connectors are routinely checked for air leakage using, e.g., the Army-standard M-14 machine. While PAD discouraged testing of candidate materials in their machines, testing was carried out with other groups and is described later in this report.

2.2.1.2 National Institute for Occupational Safety and Health (NIOSH).

Initial contacts between Hugh Carlon and Dr. Ernest S. Moyer of NIOSH took place at the annual meeting of the American Association for Aerosol Research (AAAR) held in Reno, NV, in October of 1989. Since many areas of common interest were discussed, Dr. Moyer invited Carlon to visit him at the NIOSH Division of Safety Research (DSR), in Morgantown, WV, 30 November- 1 December 1989.

The purposes of this visit were to discuss possible cooperation on DOP replacement in NIOSH respirator and filter-testing machines, to deliver and implement use of candidate replacement materials, and to develop a collaborative program of research and joint publication of results, if possible. Meetings were held with Dr. Moyer, Dr. G.P. Noonan, Dr. C. Coffey, T. Meriner, and S. Terry of the DSR technical staff.

It was fortunate that the first of our series of planned visits to sites indicating an interest in participating in our FY90 program on DOP replacement was to NIOSH. This is because NIOSH is the primary agency in the USA for the granting of certifications on filters, respirators, and other safety equipment to manufacturers and agencies interested in marketing and/or using such equipment. For example, the U.S. Army and other agencies including OSHA and the NRC state that NIOSH-approved respirators and other equipment must be used in their facilities. Thus, NIOSH's testing equipment is, in effect, "the standard" for a wide variety of commercial, military and government acceptance testing.

DSR has one standard Q-127 hot smoke machine against which filters and respirators submitted by manufacturers and other requestors must be checked for compliance. This is an ATI machine which uses DOP (because NIOSH is still mandated to use DOP under Federal law), against which all submitted equipment must be tested for compliance. While this machine is set up to produce 0.3 um diameter DOP particles with a geometric standard deviation of 1.5 or less, these requirements are not contained in their Federal guidelines. NIOSH is required only to test with DOP aerosol at a mass concentration of 100 mg/m^3 of air at continuous flow rates of 32 and 85 liters per minute for periods of 5 to 10 seconds. Three units must be tested, and total leakage must not exceed 0.03 percent of DOP concentration.

Among the manufacturers in the USA who use Q-127 machines to test their filters and respirators which are then sent to NIOSH for certification are the following (approximate number of Q-127 machines at each site is indicated in parentheses): Mine Safety Appliances (MSA), Pittsburgh, PA (5-6); Minnesota Mining & Manufacturing (3M), St. Paul, MN (10); Scott Aviation, Buffalo, NY (4-5); Wilson Safety Products, Reading, PA (2); Racal, Inc., Frederick, MD (2); Survivor Products, Los Angeles, CA (2). Virtually any manufacturer of high-efficiency particulate aerosol (HEPA) filters would be expected to have one or more Q-127 machines on site for pre-NIOSH certification testing.

The NIOSH Q-127 "standard" machine is maintained under service contract by its manufacturer, ATI, in Baltimore, MD. Thus ATI was seen as a logical local CRDEC contact whose staff should be interested in independently verifying that our DOP replacement materials would work, and meet U.S. Army specifications, in their new machines. Recently a competitor, TSI, Inc., had entered this field with a competitive machine, the Model 8110, which generates "cold smokes" with DOP to meet NIOSH testing requirements. This machine is described in Appendix F of the present report. ATI, Inc., would also be interested in testing our materials in their "cold smoke" machines to determine whether they could meet U.S. Army specifications for mask fit (leakage) and other applications.

NIOSH is not concerned with safety in the use of DOP in its standard Q-127 machine, since it operates under mandate to use DOP. However, this mandate presently is being reviewed and DOP may not be specified. Standard safety precautions are employed. The aerosol is vented to a filtered hood, and room air is routinely monitored photometrically and gravimetrically; it is claimed that no hazard can be detected. DOP is changed in the Q-127 "hot pot" every 3-4 days when machine operations are underway. This is because the DOP begins to discolor (turns brown) after a few days. The responsibility of maintaining aerosol specifications rests with the machine's manufacturer, ATI, under the service contract already mentioned. Large companies, such as 3M, calibrate test filters directly against the NIOSH machine and use these to calibrate a secondary standard machine at 3M headquarters; that machine and its filters then serve as a calibration standard for machines at other 3M sites.

Dr. Moyer maintains a very complete aerosol testing laboratory which includes a TSI cold smoke machine that was built for NIOSH and became the prototype for the Model 8110; he also has a new Model 8110 unit. He discussed with the authors a collaborative effort under which our lead technician for the DOP program, Mr. Guelta, was invited to NIOSH during 1990 for tests including operation of the Model 8110 using our DOP replacement materials, and to make laser aerosol spectrometer measurements of aerosol particle size distributions from the NIOSH standard Q-127 machine. This, and related work, will lead to a collaborative technical report under joint CRDEC/NIOSH authorship, and perhaps to other publications under similar guidelines. It also providse a strong impetus for TSI, Inc., and ATI to participate in their own studies with our DOP replacement materials.

Mr. Guelta maintained a close collaborative effort with DSR at NIOSH during 1990, including two extended visits to the Morgantown, WV, site for experimental projects. Some details of this collaboration include the following.

Testing conducted at NIOSH centered around the use of several of CRDEC's best candidate replacement materials in the TSI Model 8110 machine (Appendix F). Also, DOP smoke from the NIOSH Q-127 (TDA-100) machine was characterized, as was corn oil smoke generated in an M-14 cold smoke generator using a Laskin-style nozzle.

The TSI Model 8110 produces test aerosols at room temperature, using low pressure nubulization of the aerosolizing material. It produces aerosols in two modes; low and high concentration. In the low mode, clean compressed

air is supplied to a single nebulizer at 20 psi. In the high mode air at 30 psi is supplied to four nebulizers. The high mode can produce DOP aerosol concentrations as high as 100 mg/m^3. A felt filter pad immediately downstream of the generator removes particles approximately 0.3 um and larger from the aerosol stream. The aerosol passes into a mixing/drying chamber where dilution air is added to produce a uniform concentration.

Test aerosols were generated using DOP, Emery 3004, Emersol 875, and Emery 2219. The aerosols were generated in both the low and high concentration modes. Mean value data for several parameters of the aerosols generated are tabulated in Appendix I. Particle counts per cm^3 also are plotted there.

Samples of the test aerosols were taken both with the felt filter pad in-line, and removed. Samples taken from the TSI Model 8110 exhaust port were diluted using a TSI Model 3302 capillary diluter. The diluter aerosol stream was then characterized using a TSI Differential Mobility Sizer (DMPS, see the figure in Appendix I of the DMPS with electrostatic classifier (EC) and condensation nucleus counter (CNC).

The DMPS sizes aerosol particles over a range of 0.01-1.0 um by separating the particles due to differences in their electrical mobility. Gerbig and Keady[5] have described system components and operation of the DMPS during characterization of aerosols generated using DOP, paraffin oil, corn oil, and several glycols in a Laskin nozzle generator. The DMPS counts the number of particles present in each mobility channel, calculates the number, surface, and volume mean distributions, and assigns each a spread factor.

Aerosol mass concentration generated from each of the materials was measured by placing Whatman #40 filter paper in the test chuck and passing a known volume of the test aerosol stream through the paper. The filter paper weight was recorded before and after the test, and total aerosol flows were recorded Mass concentration data are tabulated in Appendix I, and particle counts for Emery 3004 vs. mobility channel are plotted on the same page.

DOP aerosol generated in the NIOSH Q-127/TDA-100 machine was characterized using CRDEC's LAS-X particle size analyzer. The NIOSH machine setup was similar to the ATI production machines and to our machine with the exception the vapor pickup and quench air streams. The NIOSH machine flow rates were doubled, using 40 lpm of vapor air and 160 lpm of quench air. Mean values for particle size with a 28 degree reading on the Owl ranged from 0.188 um to 0.197 um. Sigma-g was smaller than observed for other machines, having a range of 1.234 to 1.250.

Corn oil aerosols were generated using a Laskin nozzle. The cold smoke generator employed a two stage system. The lower stage contained a liquid reservoir with a Laskin nozzle immersed in corn oil. Aerosol generated in the lower stage passed through an accelerating nozzle and around an impaction plate. The impaction plate removes larger particles from the air stream. Raising or lowering the impaction plate, and altering air flow rates through the accelerating nozzle, control the particle size range.

Corn oil aerosols were characterized with 1.5 psi and 5.0 psi air supplied to the Laskin nozzle. Mean particle diameters were 0.303 um to 0.272 um, with sigma-g values of 1.82 and 1.65, respectively. Corn oil is being used in the Army's M-14 mask fit testers, as an interim replacement for DOP.

While the main emphasis of this program was replacement of DOP in filter test machines, we took opportunities to collect data generated from various cold smoke machines whenever possible. It was desirable, of course, to find one material that worked well in all types of aerosol test applications.

Prior to a second CRDEC visit to NIOSH, TSI, Inc., supplied us with test chuck parts for the Model 8110 machine that would allow testing of Army-standard C-2 gas mask canisters. Comparative testing using DOP and CRDEC candidate replacement materials in the TSI Model 8110 and the ATI was initiated. At this time, this cooperative study has not yet been completed and documented.

2.2.2 Testing with Air Techniques, Inc. (ATI).

We were invited by the management of Air Techniques, Inc.[8] to carry out comparative testing of DOP and our two best candidate replacement materials in three brand-new TDA-100 (formerly Q-127) penetrometer machines on their production line, during "break-in" in the early months of 1990. Data obtained from these tests were extremely valuable.

The materials selected for comparison with DOP were Emersol 875 isostearic acid, and Emery 3004 synthetic hydrocabron (poly alpha olefin, or "PAO"). The reservoir ("hot pot") of each machine was was filled with one of the three materials. The machines were adjusted to give smoke yields at the test chucks of 100 mg/m^3, in accordance with Army specifications. The DOP machine was adjusted according to ATI specifications for new machines, and the machines containing isostearic acid and PAO were initially set up using the control setting from our research, which were then modified slightly as needed to obtain the required smoke yields. The machines, which were identical, were then operated for 100 hours on eight-hour daily, 40-hour weekly, schedules. Samples of the materials were collected into glass vials from the hot pots after approximately every 20 hours of operation, for future chemical analyses to determine whether decomposition, polymerization, or other changes occured during this thermal "aging."

DOP and PAO were observed to have similar aging properties. Both remained clear for 10-20 hours of operation at temperature, and then exhibited a deepening honey color which turned to yellowish-brown after 100 hours. The isostearic acid, however, began to chemically attack brass parts used in the ATI machine hot pots. Within a few hours the liquid had turned greenish, and within 10-20 hours a deep greenish-black color developed. At the end of 100 hours, the material was black and quite viscous, indicating that polymerization might have been catalyzed by iron and copper complexes that were taken into solution. ATI engineers expressed an interest in experimenting with modified hot pots of stainless steel, glass, ceramic, or other inert construction, that could eliminate these corrosion problems. Such machine modifications might also reduce discoloration and sludging of DOP and other liquids used in the pots, thus increasing elapsed times to the accumulation of sludge, with required periodic maintenance, and requiring less frequent replacement of the material itself.

After the break-in period, our LAS-X and diluter systems were taken to the ATI factory for detailed measurements of the test smokes from the three machines. Trials were first run with the aged materials in the machines. The hot pots were then drained and refilled with fresh materials, and a second set of trials was run.

The new TDA-100 machines are designed around standard DOP specifications, and their operating temperatures are controlled by fixed-wattage heaters. Nevertheless, it was demonstrated that Army test specifications could be met with the new materials, without modification of the machines. ATI engineers indicated that if it were desired to deliver a new machine with, e.g., PAO instead of DOP, only a minor modification would be required to match the heater wattage to the proper operating temperature range of the replacement material, thus further improving the "monodispersity" of the of the test smoke.

After the machines were refilled with fresh materials, it was found that the specifications of the DOP and PAO smokes were very similar. Within the range of operating controls, the PAO smoke produced had a GMD of 0.22 um with a GSD of 1.29, while the DOP smoke, with optimum machine settings, had a GMD of 0.21 um with a GSD of 1.29. The fresh isostearic acid also was found to be able to produce a smoke that met Army specifications, within the available range of machine operating controls, but the latter material was not subjected to further detailed testing. Primarily because of its non-corrosiveness and better aging properties, PAO was selected as the tentative candidate of choice to replace DOP in existing Q-127 and new TDA-100 penetrometer machines with a minimum of downtime and machine modification.

Further testing at ATI with Emery 3004 allowed operators to become familiar with the range of TDA-100 adjustments and their interactions, so that smoke specifications were gradually improved using this new material. In most recent tests, Emery 3004 produced smokes with GSDs smaller than 1.25. Some representative data are presented in Appendix C.

2.3 Consultative Assistance.

2.3.1 U.S. Army Umatilla Army Depot.

On 11 June, 1990, Hugh Carlon visited the Umatilla Army Depot near Hermiston, Oregon, to discuss mask fit testing with cold smoke machines and the possible use of CRDEC-developed replacement materials for DOP.

Discussions with Umatilla mask testing personnel revealed that they, with DPG personnel, were the only two groups having moderate success in using corn oil in place of DOP for testing, even at room temperature. This success apparently resulted from careful cleaning and maintenance of their M14 machines. This involved draining and replacing the corn oil once a week, and completely disassembling the machine once a month to remove sticky residuals. Since the machines were not designed for this disassembly, the operation took an entire day per machine. Given that only one machine was operated about two days per week, part of their success might have been due to the relativly small residuals that were accumulated compared to those at other sites with more frequent operations. DOP was far easier to use than corn oil.

Much was learned that was directly applicable to PAD operations at APG and to the continuing CRDEC research program to identify safe DOP replacements. A valuable contact was stated to be Mr. Dave Chapman at Pine Bluff Arsenal, who oversees mask test operations at all depots, to learn if CRDEC materials could be substituted at one or more depots for side-by-side comparisons with DOP. This is possible because all depots must keep two M14 testers on hand- one as a spare- to insure continued operations.

2.3.2 U.S. Department of Energy (DOE).

2.3.2.1 Los Alamos National Laboratory (LANL).

At LANL, on 14-15 June 1990, detailed discussions were held on DOP replacement with CRDEC materials in hot smoke machines, and in a prototype "cold pot, hot smoke" machine built by LANL for PAD at Edgewood, the Los Alamos Monodispersed Aerosol Prototype Penetrometer (LAMAPP). Operating data and procedures were discussed for a newly-identified CRDEC material that works extremely well as a DOP replacement in the LAMAPP machine- isopropyl isostearate.

Lengthy discussions also were held concerning the toxicological evaluation for ultimate U.S. Army Surgeon General acceptance of our primary DOP replacement materials. Since Army filter test requirements are stricter than those of other Government or civilian organizations, Army acceptance would be tantamount to universal acceptance of a CRDEC material as "the" DOP replacement. The top candidate among CRDEC materials is a synthetic hydrocarbon of the class called poly-alpha olefins" (PAOs), named "Emery 3004" by its manufacturer. This material had already been approved for use at APG by the CRDEC Health and Veterinary Services Office (HVSO), and samples had been sent for in-house testing, beginning with an Ames assay screen, to support documentation that would ultimately be needed to obtain a U.S. Army Surgeon General's decision on replacement of DOP Army-wide using this material (see Appendix D).

LANL has also developed a "cold smoke" Alternative Test System (ATS) which can use DOP replacement materials identified by CRDEC. The ATS was originally evaluated by Drs. R. Scripsick and S. Solderholm. A larger version of the ATS, the High Flow Alternative Test System (HFATS) was purchased by PAD at Edgewood. The HFATS, which can deliver up to 2,000 SCFM of test aerosol, is designed to replace the Q-107 hot smoke penetrometer. This new-generation cold smoke penetrometer relies on technology advances in aerosol characterization and concentration measurements (see Appendix J). The standard "hot pot" has been replaced by Laskin nozzle generators, and a Laser Aerosol Spectrometer ("LAS-X") replaces the traditional mechanical "Owl" and light photometer for particle size and penetration measurements.

The system consists of two cold smoke generator pots, each containing four Laskin nozzle generators (Appendix J). Smoke from the generators is diluted as needed to bring the test air stream to the desired volume. A series of capillary diluters allows aerosol size measurement by the LAS-X both upstream and downstream of the test filter. Particles of all sizes are counted upstream and downstream of the filter. Filter efficiency for each particular size range is calculated by a Hewlett Packard microcomputer. Particle penetration can be printed for each bin size of interest. Usually, bin #9 represents particles of about 0.3 um count mean diameter (CMD).

During acceptance testing of the HFATS at PAD in Edgewood, Emery 3004 and Emersol 875 were used to generate the challenge aerosols. The test aerosols were found to meet the criteria of DOE Standard NE-F-3-43 which sets system requirements for QA penetration testing of high-efficiency filters. Representative particle size and penetration measurement data are tabulated in Appendix J.

2.3.2.2 Hanford Nuclear Site.

At the Environmental Health Sciences Division of the Hanford Environmental Health Foundation (HEHF), detailed discussions were held 12-13 June 1990 on DOP replacement materials for "hot smoke" machines. HEHF was then using dioctyl sebacate (DOS) to replace DOP in their Q-76, Q-107, and Q-127 testers, because the use of DOP has been curtailed owing to its possible carcinogenicity. But the DOS was causing gumming and other fouling problems not unlike those encountered with corn oil in other machines. DOE, which operates HEHF, currently was deciding whether to convert to a suitable DOP substitute such as one of our materials, or to replace their machines with new units that incorporate a completely different "cold smoke" technology and would generate smokes with much poorer "monodispersity," i.e., wider particle size distributions, than currently are achievable using hot smoke technology. DOE's filter test requirements regarding monodispersity are not as rigorous as those of the U.S. Army, although acceptable penetration levels are comparable.

2.3.3 Technical Presentations.

2.3.3.1 U.S. Government Technical Meetings.

During 1990, the CRDEC technical report[7] detailing our study of candidate replacement materials for DOP was reprocessed to obtain approval for public release with unlimited distribution. The report was then reprinted and circulated in large numbers to requestors at many technical meetings. This greatly facilitated the transfer of technology on DOP replacement to organizations outside the U.S. Government.

Mark Guelta gave a presentation titled "Safe Replacement Materials for DOP in 'Hot and Cold Smoke' Aerosol Penetrometer Machines" at the U.S. Army CRDEC Scientific Conference on Chemical Defense Research, 13-16 November 1990.

Numerous other presentations were made informally in consultative meetings with technical personnel of other U.S. Government agencies, including PAD, NIOSH, Umatilla Army Depot, LANL, and the Hanford Nuclear Site.

2.3.3.2 American Association for Aerosol Research (AAAR).

Hugh Carlon presented a paper at the 1990 Annual Meeting of the American Association for Aerosol Research (AAAR), Philadelphia, PA, on 21 June 1990. This platform presentation was titled "Experimental Study of Non-Hazardous Replacement Materials for DOP in Filter-Testing Penetrometer Machines." This paper formed the basis for a submission to the AAAR journal, as discussed below, which was subsequently accepted for publication internationally in the Spring of 1991.

The meeting was attended by over 300 scientists, of whom about 35 were involved in direct discussions involving DOP replacement problems. Our paper was presented to an enthusiastic audience of specialists, and copies of several handouts taken to the presentation were quickly exhausted. Copies were sent to those requesting them from CRDEC after the meeting.

Overall, the contacts made at the conference in fields including DOP replacement materials and their toxicology, aerosol electro-optical properties and aerosol physics, generally, were excellent. A further presentation was made to AAAR in 1991, as follows:

> H.R. Carlon and M.A. Guelta, "DOP Replacement in Testing Machines for Filters and Respirators: An Update," presented at the 10th Annual Meeting of the American Association for Aerosol Research, 7-11 Oct 1991, Traverse City, Michigan.

2.3.3.3 21st DOE/NRC Nuclear Air Cleaning Conference.

The 21st DOE/NRC Nuclear Air Cleaning Conference, co-sponsored by the U.S. Department of Energy and Nuclear Regulatory Commission, was held in San Diego, CA, 13-16 August 1990. It was without question the highlight meeting of all those at which CRDEC was represented during the year on problems related to DOP replacement and mask and filter testing, generally.

Hugh Carlon presented a paper, co-authored with Mark Guelta, titled "Safe Replacement Materials for DOP in 'Hot Smoke' Aerosol Penetrometer Machines." The paper also was accepted in camera-ready format for inclusion in the Proceedings of this conference, as follows:

> H.R. Carlon and M.A. Guelta, "Safe Replacement Materials for DOP in 'Hot Smoke' Aerosol Penetrometer Machines," Proceedings of the 21st DOE/NRC Nuclear Air Cleaning Conference," 13-16 Aug 1991, San Diego, CA, Vol. 1, 126-138.

The presentation was attended by over 100 persons, and supplies of available handouts were again quickly exhausted and had to be mailed to requestors from CRDEC after the meeting. The discussions held before, during, and after the presentation were excellent. We were also able to contribute heavily in meeting sessions dealing with aerosol optics.

Our paper as presented began with a review of the replacement problem since for many decades dioctyl phthalate (DOP), a common industrial material, has been used by the U.S. Army and other agencies to simulate aerosol behavior in non-destructive gas mask and filter serviceability testing, and for related test purposes. Techniques are completely standardized. But DOP has been labeled a hazardous material. The research reported was limited to that performed using ATI Q-127 and TDA-100 "hot smoke" aerosol penetrometer test machines. The most promising candidate materials were presented in the order shown in the left-hand column of Table 1 in the present report.

A paper updating this work has been accepted for the 1992 DOE/NRC Conference. These conferences are held once every two years.

2.3.3.4 Fine Particle Society.

This international meeting was also held 21-25 August, 1990, in San Diego, CA, during the week following the 21st DOE/NRC Nuclear Air Cleaning Conference. Hugh Carlon presented a paper, co-authored by Mark Guelta, entitled "Replacement Materials for DOP in Filter-Testing Penetrometer Machines."

The presentation was attended by scientists working in specialized areas of particle technology, of which DOP testing is a peripheral part. The tone of this meeting was much more scientific, and much less applications-oriented, than the DOE/NRC conference.

Our paper was invited for submission to the Society's international journal, "Particulate Science and Technology." A second paper was accepted and presented at the Society's 1991 Annual Meeting, as follows:

> H.R. Carlon and M.A. Guelta, "Implementation of DOP Replacement with Safe New Materials in Respirator and Filter Testing Penetrometer Machines," presented at the 22nd Annual Meeting of the Fine Particle Society, 29 Jul-2 Aug 1991, San Jose, California.

2.3.3.5 American Filtration Society.

This society has recent origins in the United States, but is a major forum for all aspects of filtration. We presented the following paper:

> H.R. Carlon and M.A. Guelta, "A Study of Candidate Replacement Materials for DOP in Filter-Testing Penetrometer Machines," presented at the Annual Meeting of the American Filtration Society, 22-24 Apr 1991, Minneapolis, Minnesota.

This paper was subsequently published in a hard-bound volume:

> H.R. Carlon and M.A. Guelta, "Replacement Materials for DOP in Filter-Testing Penetrometer Machines," in K.L. Rubow, ed., Advances in Filtration and Separation Technology, Volume 4: Fine Particle Filtration and Separation, 203-206, Gulf Publishing Co., Houston, TX (1991).

2.3.4 Publications.

2.3.4.1 U.S. Government Patents Filed.

In January of 1990, inquiries were begun into the patentability of successful DOP replacement materials that were identified in this program. The objective was to determine whether the Government's rights could be protected against having to pay royalties to manufacturers of mask and filter test machines who might repackage these materials under their own brand names- a common industry practice.

Since the individual materials and the machines in which they might be used are already covered by patents held by their respective manufacturers, the question was one of determining exactly what is patentable when successful DOP replacement materials are matched to specific testers. For example, the patent for the first light bulb was based upon the combination of carbon and glass in a new way for a specific purpose that represented a distinct improvement over prior practice. But carbon and glass, and methods to fabricate and evacuate glass bulbs, were certainly not themselves patentable.

U.S. Army Armament, Munitions and Chemical Command (AMCCOM) Patent Council, through its legal office in the Edgewood Area of APG, determined that DOP replacement materials apparently could be protected by process-type patents written for individual combinations of materials and machines. Accordingly, as of this writing, a total of 11 patent disclosures were submitted and accepted for filing by the CRDEC Invention Evaluation Committee. These are summarized in Table 4. Acceptance dates ranged from 27 April to 17 August 1990.

Three of these disclosures were selected first by attorneys at AMCCOM headqurters at Dover, NJ, for preparation and submission together as a test case for patenting. These discussed the use of Emersol 875 isostearic acid as the DOP replacement material in three different machines with docket numbers (Table 4) as follows: DAM 271-90, the LAMAPP machine; DAM 274-90, the ATI, Inc., Model TDA-100 (Q127) or comparable machines; DAM 284-90, the TSI, Inc., Model 8110 Automated Filter Tester or comparable machines. The three patents were prepared during November, 1990, and were expected to be filed officially shortly thereafter.

The three patents were filed under the title "An Improved Method of Testing a Filter for Gas Masks, Respirators and Other Personal Protective Equipment." Where patents have since issued, their numbers appear in parentheses in Table 4, e.g., (5,080,829) for DAM 271-90.

2.3.4.2 U.S. Government Reports and Proceedings.

A brief CRDEC Special Publication[12] reports the computer data base search and procedures that were carried out in the early stages of our DOP replacement program, in an attempt to find suitable candidate materials of low toxicity and improbable carcinogenicity/mutagenicity for testing.

The detailed report describing our study of candidate replacement materials[7], which has subsequently been approved for unlimited public release and distribution as mentioned earlier, is available upon request from the present authors.

The published Proceedings of the U.S. Army CRDEC Scientific Conference on Chemical Defense Research, 13-16 November 1990, included Mark Guelta's presentation, with Hugh Carlon, titled "Safe Replacement Materials for DOP in 'Hot and Cold Smoke' Aerosol Penetrometer Machines."

Table 4. U.S. Government Patent Disclosures Filed on DOP Replacement.

Acceptance Date for Patenting	Docket Number DAM-	Title	Inventors[7]
27 Apr 90	271-90 (5,080,829)	Process for Replacement of DOP with Liquid Isostearic Acid[a] in Cold Pot Filter-Testing Penetrometer Machines.[x]	Carlon, Guelta & Gerber
27 Apr 90	272-90 (5,059,349)	Process for Replacement of DOP with 4 CST Poly-Alpha Olefin[b] in Hot Pot Filter-Testing Penetrometer Machines.[y]	Carlon, Guelta & Gerber
27 Apr 90	273-90 (5,059,352)	Process for Replacement of DOP with 2 CST Poly-Alpha Olefin[c] in Cold Pot Filter-Testing Penetrometer Machines.[x]	Carlon, Guelta & Gerber
27 Apr 90	274-90	Process for Replacement of DOP with Liquid Isostearic Acid[a] in Hot Pot Filter-Testing Penetrometer Machines.[y]	Carlon, Guelta & Gerber
17 Aug 90	278-90 (5,059,350)	Process for Replacement of DOP with 6 CST Poly-Alpha Olefin[d] in Hot Pot Filter-Testing Penetrometer Machines.[y]	Carlon, Guelta & Gerber
17 Aug 90	280-90 (5,059,353)	Process for Replacement of DOP with Oleic Acid[e] in Hot Pot Filter-Testing Penetrometer Machines.[y]	Carlon, Guelta & Gerber
17 Aug 90	281-90 (5,087,389)	Process for Replacement of DOP with Technical Grade Isostearic Acid[f] in Hot Pot Filter-Testing Penetrometer Machines.[y]	Carlon, Guelta & Gerber
16 Aug 90	282-90 (5,059,351)	Process for Replacement of DOP with Methyl Oleate Stearate[g] in Cold Pot Filter-Testing Penetrometer Machines.[x]	Carlon, Guelta & Gerber
17 Aug 90	284-90 (5,059,348)	Process for Replacement of DOP with Liquid Isostearic Acid[a] in a Cold Smoke Automated Filter Tester.[z]	Guelta & Carlon
17 Aug 90	285-90 (5,076,965)	Process for Replacement of DOP with 4 CST Poly-Alpha Olefin[b] in a Cold Smoke Automated Filter Tester.[z]	Guelta & Carlon
17 Aug 90	292-90	Process for Replacement of DOP with Isopropyl Isostearate[h] in Cold Pot Filter-Testing Penetrometer Machines.[x]	Guelta & Carlon

a = Emersol 875   b = Emery 3004   c = Emery 3002   d = Emery 3006
e = Industrene 206LP   f = Emersol 871   g = Emery 2219   h = Emerest 2310

x = Los Alamos Monodispersed Aerosol Prototype Penetrometer (LAMAPP) machine.
y = Air Techniques, Inc., Model TDA-100 (Q127) or comparable machines.
z = TSI, Inc., Model 8110 Automated Filter Tester or comparable machines.

2.3.4.3 Proceedings of International Conferences.

The invited paper "Safe Replacement Materials for DOP in Filter-Testing Machines," by Hugh Carlon and Mark Guelta, was accepted for platform presentation and publication in the Proceedings of The 3rd International Aerosol Conference 1990, 24-27 September 1990, in Kyoto, Japan. When travel funds restrictions prevented Carlon from making the presentation, he was informed by Dr. Kanji Takahashi, General Secretary of the Organizing Committee for the conference, that since the paper would not be presented it could not be included in the Proceedings.

2.3.4.4 Research Papers in the Open Literature.

An invited journal paper based on the presentation given by Hugh Carlon to the Fine Particle Society in August 1990, was submitted to the official periodical of that society: "Particulate Science and Technology, an International Journal;" Mark Guelta was co-author. The paper was titled "Replacement Materials for DOP in Filter-Testing Penetrometer Machines." At this writing, its status regarding acceptance is unknown.

A research paper by Hugh Carlon, Mark Guelta, and Bernard Gerber titled "Some Candidate Replacement Materials for Dioctyl Phthalate in 'Hot Smoke' Aerosol Penetrometer Machines" was published in the AAAR journal "Aerosol Science and Technology," 14:233-246 (1991). This journal is published by Elsevier Publishing Company.

3. APPROVALS REQUIRED FOR FINAL IMPLEMENTATION

3.1 Local (Aberdeen Proving Ground).

Based upon information provided (Appendix D) to the CRDEC Health and Veterinary Services Office (HVSO), on 11 April 1990 that office concurred with the use of Emery 3004 as a substitute for DOP in filter penetrometers used by CRDEC/AMCCOM elements at Edgewood subject to routine engineering and work practice controls. HVSO also subsequently staffed the issue to higher headquarters, as a required step to eventaully obtain U.S. Army Surgeon General approval for use of this material Army-wide.

Concurrence with CRDEC/AMCCOM testing greatly facilitated testing with Emery 3004 in the Edgewood Area of APG involving elements of CRDEC and Product Assurance Directorate (PAD), as discussed elsewhere in this report.

At the same time, HVSO forwarded a memorandum to the U.S. Army Environmental Health Agency (AEHA), which acts for the U.S. Army Surgeon General in such matters, requesting comments on the use of Emery 3004 as a substitute for DOP in penetrometer filter test operations to resolve any major issues prior to staffing this request to higher headquarters to get DA approval for the use of this compound.

3.2 Army-Wide (U.S. Army Surgeon General).

On 2 May 1990, a response was received to the HVSO memorandum from the Chief, Toxicology Division, AEHA, requesting further data on the expected airborne concentrations and chemical structures of poly-alpha olefins

(PAOs) including Emery 3004 as an aid in assessing potential health effects. It was asked whether Emery 3004 is comparable structurally Emery 3002 or 3006 (it is not the same- See Table 3 and Appendix B).

Finally, the memorandum from AEHA to HVSO stated that, although these compounds appear to present a minimal toxicological hazard, data are needed related to potential long term health effects. As a very minimum, a "test battery of mutagenic assays" was recommended as a "rough preliminary screen for diseases such as cancer and some developmental effects." The test battery should include assays for point mutations (e.g., the Ames) and clastogenic changes, i.e., breaks in chromosomes.

The memorandum concluded that if these compounds do not possess mutagenic activity and worker exposure levels are sufficiently low (less than 5 mg/m^3), "there is probably sufficient information to argue for approving PAOs as a substitute for DOP."

This guidance led us to initiate the first in a series of what would probably be several studies of escalating complexity and cost- the Ames assay discussed earlier in Section 2.1.2. White[13] has given a brief but useful summary of short-term assays that have been developed to measure data for predicting genotoxicity and carcinogenesis.

The "tier approach" to mutagenicity testing is advocated at CRDEC. Tier 1 is designed to show primary capacity of the test compound for genotoxic effects at minimal cost. Screening of compounds for more costly test procedures can be accomplished in this tier, but results should not be used to estimate risk to mammalian systems. One of three gene mutation procedures normally is done involving microbes or mammalian cells- most frequently it is the Ames assay which we have already completed successfully for the compound Emery 3004.

Tier 2 assays for gene mutation utilize in vivo and host mediated tests which usually are considered in making mutagenicity risk assessments in mammalian systems, such as the Sex-Linked Recessive Lethal Test that is conducted at CRDEC using fruit flies. Other tests including those for chromosomal aberrations and primary DNA damage would have to be performed out-of-house on contract.

Tier 3 test protocols are more costly, longer term, in vivo studies that should be used to confirm results of less costly in vitro studies of the lower tiers. Information accumulated from the lower tiers should indicate which of these in vivo studies to use. Because they are long term fully in vivo mammalian studies they are usually relied on more heavily in assessing risk to humans. CRDEC conducts the Dominant Lethal Mutation Test in Rats. Others such as lung adenoma in mice, heritable translocations in rats, or specific locus tests in mice, would have to be performed on contract. The actual series of three-Tier testing was carried out as discussed below, following encouraging analyses of Emery 3004 and DOP side-by-side for chemical or thermal degradation. See the Memorandum dated 11 July 1990, SUBJECT: Analysis of DOP/Emery Samples, in Appendix E.

The Ames system assay was completed successfully and reported upon on 22 August 1990. See the Memorandum of that date, SUBJECT: Mutagenicity Testing of Emery 3004, in Appendix E. It was concluded that no evidence of mutagenic potential was found in this testing, but that additional tests were needed for human risk assessment.

Tier 2 testing used the sex-linked recessive lethal test in Drosophilia melanogaster (fruit flies), which measures the occurence and frequency of lethal mutations, both point mutations and small deletions, in the germ cell line of the fruit fly. Details are given in Appendix E in the Memorandum with SUBJECT: Mutation Tests of Emery 3004, signed by the Chief, Toxicology Division, CRDEC. The mutation results, as tested, classified Emery 3004 as a non-mutagen in the assay system used.

Tier 3 testing used the rodent bone marrow micronucleus assay, and was performed by the contractor Integrated Laboratory Systems, Research Triangle Park, NC 27709. Their report dated 31 October, 1991, (see Appendix E), concluded that "multiple treatments with Emery 3004 synthetic hydrocarbon 4CST fluid did not result in a significantly increased frequency of MN-PCE in the bone marrow of male B6C3F1 rats.' 'In addition, the test article did not significantly depress the percentage of PCE in either experiment."

On 15 March 1991, the Health and Veterinary Services Office (HVSO), CRDEC, staffed a letter to the Army's Office of the Surgeon General (OTSG), requesting approval of Emery 3004 as an Army-Wide substitute material for DOP (Appendix E). This was followed by a similar request from the Army Environmental Health Agency (AEHA, Appendix E), dated 24 December 1991, which summarized the structure, toxicity testing, and recent mutagenicity testing of Emery 3004. AEHA recommended that "Based on the relatively low order of toxic effects exhibited by Emery 3004, the absence of demonstrated mutagenic activity, and the relatively low exposure potential, recommend approval for the use of this substance as a replacement for dioctyl phthalate in filter test apparatus."

On 8 January 1992 (Appendix E), the OTSG responded. "SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)." "This office concurs with AEHA's recommendation of approval for use of the subject compound as a replacement for dioctyl phthalate." No restrictions on use were given. Thus Emery 3004 can be used in "hot smoke" machines, in which it performs exceptionally well, and for "cold smoke" or general aerosol testing as well.

3.3 Other Agencies and Private Sector.

In general, U.S. Army requirements and restrictions concerning the use of DOP in testing operations are at least as strict as those of any other agencies in U.S. Government or private sectors, the latter including industry and academia. Therefore it seems highly like that with the OTSG approval of Emery 3004 as a DOP replacement material, eventually to be used for testing Army-wide, this material will also gradually become accepted for more universal use. This assumes that cost, availability, and other factors affecting use of this material will remain comparable to those for DOP, as is presently the case.

4. DISCUSSION

4.1 General.

With the OTSG approval of Emery 3004 as a universal replacement for DOP, it becomes very important that availability, cost, specifications, and other information concerning Emery 3004 be made available now to potential purchasers and users. Our source of Emery 3004 (as well as 3006 and 3008, but not 3002), from stock, presently is:

Henkel Corp.
Emery Group
11501 Northlake Drive
Cincinnati, Ohio 45218 (800) 543-7370

At Emery Group, the contact to whom questions should be addressed is Mr. Mark Margeson at (513) 530-7426; secretary Diana Horton is at (513) 530-7428. At least two petroleum companies, Chevron an Ethyl Corp., have plants presently making millions of pounds of PAOs per year, to strict and reproduceable specifications. Because of the wide demand for PAOs among oil companies producing synthetic lubricants for the automotive and other industries, it is likely that these plants will remain in production indefinitely.

The recent construction of new PAO plants in Europe has caused prices for these materials at the present time to drop to historic lows. As of October, 1991, prices for Emery 3004 delivered from Cincinnati in 375 pound drums were as follows:

EMERY 3004

1 drum	$0.95 per lb.			
2-4 drums	0.89	"	"	
5-24 "	0.84	"	"	
25-79 "	0.80	"	"	
>80 "	0.77	"	"	("full truck")

Smaller quantities, e.g., pails, also are available if the user pays shipping. As a hedge against future changes in specifications, the Army could consider sampling an initial lot, subjecting it to QC measurements, testing with it in various smoke machines to assure performance, and then buying a large number of drums to form its own "stockpile" from which to draw in future years. Since the total amounts used are not great, the needed stockpile size could be worked out by PAD. It is worth noting that ATI in Baltimore, manufacturers of the Q127 "hot smoke" machines, have found that DOP purchased from Eastman Kodak works well in their testing, while DOP from Monsanto does not work at all, probably due to impurities or additives. Thus a known stockpile might represent a reasonable precaution, consistent with future directions in Army filter and mask testing evolving from new penetrometer technology that might one day obsolete current, expensive, but in-place equipment.

We have told the Emery Group that we can provide them with recent data on mutagenicity testing with Emery 3004 at three "tiers" of difficulty. These were required for the OTSG submission, and could usefully be added

to MSDS (Material Safety Data Sheets) for this material since present sheets are based on old testing of Emery 3002 that greatly exaggerated the potential toxicity of these materials.

In our research program, discussed in this report and sponsored by PAD, dozens of materials were selected for test due to their low toxicities and physical properties similar to those of DOP. Some were found to produce smokes similar to those produced using DOP, in demanding vaporization-recondensation processes as are used in the Q127 (TDA-100) mask canister testing machines. "Hot smoke" machines of this kind not only place operators at greater risk of exposure than "cold smoke" machines," but require that near-monodispersed smokes be produced for optimum testing.

"Emery 3004," one of a family of poly-alpha olefins used in newer synthetic lubricants, was identified as a material that actually out-performed DOP in many machines simply by replacing the DOP and making minor front-panel temperature adjustments. Emery 3004 is produced by the direct polymerization and hydrogenation of decene-1, a 10-carbon-chain molecule with a double bond at one end, to form only the dimer (20-carbon molecule), trimer, quatrimer, etc., which are mixed in a distillation column to produce lubricants having desired viscosities.

Unlike natural oils containing carbon chain lengths of all sizes (e.g., 19, 20, 21, 22, etc.), the Emery materials vaporize almost as single compounds of 20, 30, 40, etc., carbons and recondense into almost identical droplet size distributions (giving near-monodispersity) at only a few mean droplet diameters that are widely separated from one another.

Once its superior qualities were identified, Emery 3004 was subjected the three progressively more demanding levels of mutagenicity testing, concluding with the rodent bone marrow mononucleus test. All testing was passed without evidence of mutagenicity. Based upon the relatively low order of toxic effects exhibited by Emery 3004, the absence of demonstrated mutagenic activity, and the relatively low exposure potential, AEHA recommended approval for the use of this substance as a replacement for DOP in filter test apparatus. Favorable action by the OTSG was taken on 8 January 1992, as discussed previously.

Emery 3004 should provide a solution to a long-standing problem in U.S. Army testing. It will greatly reduce maintenance of machines using other DOP substitutes, and in many cases will actually improve testing. With the approval now given by the OTSG, non-military users are expected to follow suit worldwide. To date 11 patents have been filed, of which nine have already issued, protecting the Government's interest in these research findings.

On 22 January 1992, Dr. David Steffen contacted the authors. He is with the Westinghouse-Hanford Co., which operates the former Hanford Nuclear Reservation near Richland, WA. He discussed the results of their recently concluded test program. In these tests, Hanford evaluated Emery 3004 as a replacement for DOP in the more than 100 "hot smoke" filter testing machines on the Hanford reservation. Their results confirmed almost exactly the results published earlier by the present authors. The Hanford operators found that:

- Emery 3004 could be used to directly replace DOP in their machines with simple, front-panel adjustments;

- the specifications of the Emery 3004 test smokes were at least as good as, and frequently better than, those of DOP smokes;

- because replacement, or even modification, of their existing machines could be avoided while not compromising (or, even improving) test performance, Emery 3004 would result in great cost savings as well as in reduced maintenance compared to other replacement materials.

4.2 Use of Replacement Materials in "Hot Smoke" Machines.

"Hot Smoke" machines can generally be classified as those which use the vaporization/recondensation process to form aerosols that approach monodispersity in their size distributions. A straightforward example is the ATI Model TDA-100 Monodispersed Aerosol Penetrometer (Appendix G), in which the liquid in the "hot pot" is heated to temperatures approaching 200 ^{o}C to produce sufficient vapor which is then air-quenched to form a nearly monodispersed aerosol. The best-performing materials to replace DOP in these machines have been shown to be Emery 3004, and isostearic acids (see Table 1).

A variation on the "hot smoke" machines is the LANL "LAMAPP" machine,[7] in which Laskin nozzles are used at room temperature to spray droplets of a smoke material and, from a separate reservoir, water containing NaCl. The NaCl liquid aerosol dries into tiny salt nuclei as it passes through a heating column in which the smoke liquid droplets are also evaporated. In an air quenching chamber, the evaporated liquid recondenses on the salt nuclei to form a nearly monodispersed test aerosol. Because properties of the smoke liquid other than vapor pressure (e.g., viscosity) become important in a spraying process, it is found that Emery 3002 works better than Emery 3004 in the LAMAPP machine (see Table 1). Emery 3002 has a 2 CST viscosity at 100 ^{o}C, which Emery 3004 has a 4 CST viscosity at the same temperature.

In general, the specifications for hot smokes are much more rigorous than those for cold smoke testing. At higher temperatures, thermal aging and chemical degradation can be troublesome, and high vapor concentrations require that the materials used be non-toxic and non-mutagenic in case of worker exposure. Thus, a "safe" smoke for hot testing, e.g. Emery 3004, is also a prime candidate for "cold smoke" testing.

4.3 Use of Replacement Materials in "Cold Smoke" Machines.

One example of a "cold smoke" machine is the TSI, Inc. Model 8110 Automated Filter Tester which was discussed earlier (see Appendix F). While the main emphasis of this program has been upon the replacement of DOP in hot smoke machines, we have found that several of our replacement materials also work well in various cold smoke machines. We have discussed several cold smoke machines that use either nebulization or Laskin nozzles to generate a polydispersed aerosol.

This type of aerosol generation can be used for filter cartridge testing. TSI, Inc., manufactures several automatic filter test machines (see Appendix F and Appendix K). Both ATI and TSI, Inc., produce machines for col-

lective protection filter testing, gas mask fit testing, in-place filter testers using portable aerosol generators, and particle detection systems.

These machines and systems have traditionally used aerosol materials including DOP, NaCl, corn oil, paraffin or mineral oils. But each of these materials has one or more drawbacks relating to operational problems including maintenance, or occupational exposure to machine operators. We have found that for aerosol generation by nebulization or using Laskin nozzles, Emery 3004 works as well as or better than other materials currently being used. Thus, one recommendation (below) is that users of cold smoke systems consider the use of Emery 3004 as their aerosolizing material.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions.

We conclude that Emery 3004:

- performs at least as well as DOP in hot-smoke filter penetrometer machines, and in many other machines and applications as well:

- is inexpensive, readily-available (and should continue to be so in the foreseeable future);

- is readily specifiable, unlike natural petroleum products;

- can replace DOP directly in existing penetrometer and other machines without machine modification, simply by adjusting existing machine controls;

- is non-corrosive, clean to work with, free of natural impurities, thermally and chemically stable;

- is a non-mutagen, safe to work with, and approved for Army-wide use without restriction as a replacement for DOP by the Army's Office of the Surgeon General.

5.2 Recommendations.

We recommend that:

- the use of Emery 3004 to replace DOP in testing Army-wide be implemented as soon as is practicable;

- the Army consider stockpiling Emery 3004 since it is currently at an all-time low cost, is used in relatively small quantities but in many machines, is non-corrosive and would store indefinitely, and could be purchased from a large, single production batch to insure precise specifications;

- information concerning Emery 3004 be made available to, and that its use as a DOP replacement be encouraged by, other Government services and agencies, and non-Government companies and laboratories, as well.

Table 5. Summary and Identification of Some Materials Investigated in This Study.

Chemical Name	Trade Name	CAS Number
di(2-ethylhexyl) phthalate	DEHP, DOP	117-81-7
isopropyl isostearate	Emerest 2310	68171-33-5
isostearic acid	Emersol 871, 875	30399-84-9
methyl oleate	Emery 2219	112-62-9
oleic (fatty) acid	Emersol 233 LL	112-80-1
polyalphaolefin (synthetic aliphatic hydrocarbon):		
2 CST	Emery 3002	68649-11-6
4 CST	Emery 3004	68649-12-7
6 CST	Emery 3006	68649-01-4

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6. Murrow, J.L., and Nelson, G.O., "HEPA-filter testing: Comparison of DOP and NaCl aerosols," Proc. 12th A.E.C. Air Cleaning Conference; Vol. 12:808-816 (1973).

7. Carlon, H.R., Guelta, M.A., and Gerber, B.V., "A study of candidate replacement materials for DOP in filter-testing penetrometer machines," Technical Report CRDEC-TR-053, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD 21010-5423, March 1989.

8. Air Techniques, Inc. (ATI), Division of Hamilton Associates, Inc., 11,403 Cronridge Drive, Owings Mills, MD 21117-2247, (410) 944-6037.

9. "Emery" and "Emersol" products are available from Emery Group, Henkel Corp., 11501 Northlake Drive, Cincinnati, OH 45249-1643, (513) 530-7418. "Industrene" products are available from Humko Chemical Div., Witco Chemical Corp., P.O. Box 125, Memphis, TN 38101, (901) 320-5941.

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APPENDIX A

Material Safety Data Sheets (MSDS) for DOP and Prime Candidate Replacement Materials

See Tables 1 and 4 for additional data concerning these materials and their manufacturers. MSDS are included here for the materials listed below. The two primary candidate materials are presented after the standard DOP material, followed by other materials grouped by type. The final material, Emerest 2310 Isopropyl Isostearate, also available from Emery Group,[9] has been shown recently to perform well in cold smoke machines (see text), and has a patent pending (see Table 4).

Aristech Dioctyl Phthalate (DOP)

Emery 3004 Poly-Alpha Olefin (PAO)

Emersol 875 Isostearic Acid (76%)

Emersol 871 Isostearic Acid (66%)

Emery 3002 Poly-Alpha Olefin (PAO)

Emery 3006 Poly-Alpha Olefin (PAO)

Emery 2219 Methyl Oleate Stearate

Industrene 206LP Oleic Acid (71%)

Emersol 233LL Oleic Acid (74%)

Emerest 2310 Isopropyl Isostearate

ARISTECH Aristech Chemical Corporation | **Material Safety Data Sheet**

ARISTECH CODE NO. C1007E **ORIGINAL ISSUE DATE:** 10/17/85 **REVISED:** 08/01/90

I. IDENTIFICATION

ARISTECH INFORMATION & EMERGENCY TELEPHONE NUMBERS
(412) 433-7654 (8 a.m.-5 p.m., Mon.-Fri.)
(412) 571-5888 (Off Hour Emergencies)

PRODUCT NAME: Di (2-ethylhexyl) phthalate
COMMON NAME: PX 138; DOP; DEHP; Bis (2-ethylhexyl) phthalate, Di-sec-octyl phthalate
FORMULA: $C_6H_4(COOHC_8H_{17})_2$

MANUFACTURER:
Aristech Chemical Corp.
600 Grant Street
Pittsburgh, PA 15230-0250

II. INGREDIENTS AND RECOMMENDED OCCUPATIONAL EXPOSURE LIMITS

COMPONENT	% WT.	CAS NO.	EXPOSURE LIMITS		ORAL LD_{50}	DERMAL LD_{50}
			OSHA-PEL	ACGIH-TLV		
Di (2-ethylhexyl) phthalate*	100	117-81-7	TWA 5mg/m3 STEL 10mg/m3	TWA 5mg/m3 STEL 10mg/m3	30,600 mg/kg (rat)	25gm/kg (rabbit)

HAZARD DATA
Caution! May cause allergic skin reaction. May cause skin, eye and respiratory tract irritation. Possible cancer hazard. May cause cancer hazard based on animal data risk of cancer depends on duration and level of exposure.

INGREDIENT HAZARD INFORMATION
*Di (2-Ethylhexyl) Phthalate is identified as a SARA Section 313 chemical.

III. PHYSICAL DATA

BOILING POINT (Deg. F) @ 5mmHg	446	SPECIFIC GRAVITY (H2O = 1) @ 25 Deg. C	0.982
MELTING POINT (Deg. F)	Not Applicable	PERCENT, VOLATILE BY VOLUME (%) @ 70 F	Negligible
VAPOR PRESSURE (mm Hg.) @ 0 Deg. C	Negligible	pH	Not Applicable
VAPOR DENSITY (AIR = 1)	13.5	SOLUBILITY IN WATER	.02%

APPEARANCE AND ODOR:
Clear liquid with a mild odor

IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (method used)	FLAMMABLE LIMITS	Lel	Uel
420 Deg.F (COC)	@ 474 Deg. F	0.3	Unknown

EXTINGUISHING MEDIA
Water fog, foam, carbon dioxide, dry chemical

SPECIAL FIRE FIGHTING PROCEDURES
Burning of the product will result in the release of toxic fumes. Firefighters should wear self-contained breathing apparatus and protective clothing. Use water to keep fire exposed containers cool.

UNUSUAL FIRE AND EXPLOSION HAZARDS
Water or foam may cause frothing.

V. REACTIVITY DATA

Stability	Unstable		CONDITIONS TO AVOID: None known.
	Stable	X	

INCOMPATIBILITY (materials to avoid)
Nitrates, strong oxidizers, strong acids and strong alkalies

HAZARDOUS DECOMPOSITION PRODUCTS
Carbon monoxide, carbon dioxide, organic acid

ARISTECH CODE NO. C1007E is continued on the next page.

NOTE: THIS IS THE DOP BRAND SPECIFIED BY ATI FOR USE IN ITS TDA-100 MACHINES

Polymerization	May Occur		CONDITIONS TO AVOID: None known
	Will Not Occur	X	

VI. SPILL OR LEAK PROCEDURES

TRANSPORTATION EMERGENCIES
Call CHEMTREC 800-424-9300

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:
When material is in contact with hot objects, avoid excessive breathing of fumes. Remove ignition sources. Cover with an excess of absorbent inorganic material (vermiculite). Sweep up and place in labelled drum. Bis (2-ethylhexyl) phthalate is a CERCLA hazardous substance, as amended, and reportable spills must be reported to the National Response Center.
In case of release to the environment, report spills to 800-424-8802, The National Response Center.

WASTE DISPOSAL METHOD:
Dispose of in accordance with local, state and federal regulations.

VII. HEALTH HAZARD DATA

MAJOR EXPOSURE HAZARD

[ ] INHALATION	[X] SKIN CONTACT	[X] EYE CONTACT	[ ] INGESTION

EFFECTS OF OVEREXPOSURE:
INHALATION: Due to its low vapor pressure, the inhalation exposure hazard potential is regarded to be low. However, if the product is heated, misted or sprayed, concentrations above the recommended exposure limit may cause irritation to the mucous membranes and upper respiratory tract.
SKIN CONTACT: Excessive contact may produce at least mild irritation, skin sensitization an allergic dermatitis.
EYE CONTACT: Exposure to the liquid or mist may produce at least mild irritation.
INGESTION: May cause nausea, vomiting and diarrhea. See - "Other Comments" for additional toxicology data and refer to DEHP Addendum Sheet for a summary and interpretation of toxicology testing on DEHP.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE:
Individuals with chronic respiratory disorders (i.e., asthma, chronic bronchitis, emphysema, etc.) may be adversely affected by any fume or airborne particulate matter exposure.

CARCINOGENICITY

[X] NTP	[X] IARC	[ ] OSHA

ARISTECH CODE NO. C1007E is continued on the next page.

NOTE: THIS IS THE DOP BRAND SPECIFIED BY ATI FOR USE IN ITS TDA-100 MACHINES

OTHER COMMENTS:
The major target organs showing DEHP-related toxicity in animals are the liver and testes. DEHP causes liver enlargement and peroxisome proliferation in rodents. Very high dietary levels of DEHP produced liver cancer in mice and rats of both sexes (NTP 4th Annual Report Summary, pg 83, 1985). DEHP also causes testicular damage and reduced fertility in males and fetotoxicity and teratogenicity in pregnant female rodents (Environ. Health Persp. 1982, 45; Tox. Appl. Pharmcol. 1980, 53:35-41). Refer to DEHP Addendum Sheet for a more complete summary and interpretation.

DEHP Toxicology Summary

The toxicity of DEHP has been questioned, especially since the National Cancer Institute (NCI) reported in 1980 that very high dietary levels of the plasticizer caused liver tumors in mice and rats of both sexes in a lifetime feeding study. Extensive toxicology studies on DEHP have been reviewed and reported to the Consumer Product Safety Commission (CPSC) by the Chronic Hazard Advisory Panel (CHAP) on DEHP (1985).

The Special Programs Division of the Chemical Manufacturers Association (CMA) continues to sponsor research on the safety of phthalate esters in a program established in consultation with the EPA. Aristech has been an active member of this research effort. Currently the CMA program is sponsoring metabolism studies, mutagenicity studies, and studies on liver toxicity of DEHP. The findings of this work are briefly summarized here, and more detailed information can be obtained from CMA.

- DEHP and its metabolites are not genotoxic. The majority of chemicals that cause tumors do so by damaging genetic material.

- DEHP appears to belong to a special class of non-genotoxic carcinogens that share the properties of inducing liver enlargement and liver peroxisomal proliferation in mice and rats. These liver changes may be unique to these rodents and may not occur in other animal species, including man. A plausible mechanism of action for this type of carcinogenesis appears to involve the induction of liver peroxisomes (Environ. Health Perspec. 45, 35-40, 1982). This hypothesis implies a possible threshold for DEHP carcinogenicity.

- DEHP metabolism studies have demonstrated significant quantitative differences between rats and primates. These studies, conducted at the same extremely high doses used in the NCI bioassay, caused changes in the livers of rodents which are not seen at more realistic dose levels. This data may imply equally significant differences in the susceptibility of these species to the carcinogenic effects of DEHP.

- In summary, the NCI bioassy on DEHP at very high dietary levels resulted in a carcinogenic effect that appears unique to rodents. The relevance of this bioassay to lower dose levels and to humans is seriously questioned.

VIII. EMERGENCY AND FIRST AID PROCEDURES

EMERGENCY AND FIRST AID PROCEDURES:
INHALATION: Remove from exposure. If breathing is difficult or has stopped, administer artificial respiration (mouth-to-mouth) or oxygen as indicated. Call a physician.
SKIN CONTACT: Remove contaminated clothing. Wash skin thoroughly with soap and plenty of water. Call a physician.
EYE CONTACT: Flush with large quantities of lukewarm water, for at least 15 minutes. Call a physician.
INGESTION: Give 1-2 large glasses of water or milk. Induce vomiting by touching finger to the back of throat. Call a physician.

IX. SPECIAL PROTECTION INFORMATION

RESPIRATORY:
Respiratory protection approved by NIOSH/MSHA for protection against organic vapors should be used to avoid inhalation of excessive air contaminants. Appropriate respirator selection depends on the type and magnitude of exposure.

SKIN:
Chemical resistance data for barrier materials used should be determined based on the use of this product. Natural rubber, neoprene, polyvinyl chloride and nitrile protective garments have been suggested for protection against materials of this chemical class (ACGIH Guidelines for the Selection of Chemical Protective Clothing, 1983).

EYE:
Employees should be required to wear chemical safety goggles to prevent eye contact. A face shield should be used when appropriate to prevent contact with splashed materials.

VENTILATION:
Local exhaust ventilation should be used to control the emission of air contaminants. General dilution ventilation may assist with the reduction of air contaminant concentrations.

OTHER PROTECTIVE EQUIPMENT:
Emergency eye wash stations and deluge safety showers should be available in the work area.

ARISTECH CODE NO. C1007E is continued on the next page.

NOTE: THIS IS THE DOP BRAND SPECIFIED BY ATI FOR USE IN ITS TDA-100 MACHINES

SECTION IX. SPECIAL PROTECTION INFORMATION (continued)

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:
Store in a well-ventilated area away from oxidizing agents and sources of heat or ignition. Follow good hygienic practices to avoid potential chronic effects. Contaminated clothing should be removed and laundered before reuse. Avoid repeated or prolonged contact with the liquid and inhalation of mists or vapors. Do not eat or smoke in areas where this material is used or stored.

X. REGULATORY STATUS

TSCA STATUS: This product (or its ingredients if it is a mixture) appears on the Toxic Substances Control Act Inventory (TSCA).

SARA HAZARD CATEGORIES (Section 311 and Section 312)

	REACTIVITY		PRESSURE		FIRE
X	IMMEDIATE HEALTH	X	DELAYED HEALTH		

SARA Section 313: See Section II, Ingredient Hazard Information.

DOT SHIPPING NAME:
Hazardous substance, liquid, n.o.s., (Bis (2-ethylhexyl) phthalate)

DOT HAZARD CLASS:	IDENTIFICATION NUMBER:
ORM-E	NA 9188

HMIS RATINGS (Hazardous Materials Identification System, Scale 0-4)

1	HEALTH	1	FLAMMABILITY	0	REACTIVITY

NFPA RATINGS (National Fire Protection Association, Scale 0-4)

1	HEALTH	1	FLAMMABILITY	0	REACTIVITY

If you require additional information regarding any legal or regulatory requirement referred to in this MSDS, we suggest that you consult with an appropriate regulatory agency, or with a professional with expertise in the area.

This information is taken from sources or based upon data believed to be reliable; however, Aristech Chemical Corporation makes no warranty as to the absolute correctness or sufficiency of any of the foregoing or that additional or other measures may not be required under particular conditions.

NOTE: THIS IS THE DOP BRAND SPECIFIED BY ATI FOR USE IN ITS TDA-100 MACHINES

H E N K E L   C O R P O R A T I O N

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297   **CHEMTREC** 800-424-9300

MSDS REFERENCE: EMERY 3004 (3/31/89)

SECTION I - IDENTIFICATION

PRODUCT: EMERY 3004 SYNTHETIC HYDROCARBON 4 CST FLUID

SYNONYMS: POLYALPHAOLEFIN

CHEMICAL: SYNTHETIC ALIPHATIC HYDROCARBON

CAS NO: 68649-12-7

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
POLYALPHAOLEFIN (68649-12-7)	100	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: THE ESTIMATED LC50 FOR A 1 HOUR EXPOSURE TO 2 CST PAO WAS 4.68 MG/L (RATS), WHICH IS CONSIDERED TOXIC. IN ORDER TO DETERMINE THE LC50 VALUE, EXTREMELY HEAVY MISTS OF PAO WERE REQUIRED. THE VERY HEAVY MISTS AT THE NECESSARY CONCENTRATION MADE VISIBILITY DIFFICULT AND WOULD BE DIFFICULT TO WORK IN FOR ANY PERIOD OF TIME. THE AUTHOR REPORTED THAT HISTOPATHOLOGICAL CHANGES MAY HAVE BEEN A RESPONSE TO A PHYSICAL INSULT RATHER THAN A SPECIFIC COMPOUND RELATED TOXICITY EFFECT AND THAT 2 CST PAO MAY BE CONSIDERED NON-HAZARDOUS FOR ALL PRACTICAL PURPOSES BY INHALATION.

INGESTION: THE ACUTE ORAL LD50 VALUE WAS FOUND TO BE GREATER THAN 5.0 G/KG IN MALE AND FEMALE SPRAGUE-DAWLEY RATS. THE MATERIAL IS NOT CLASSIFIED AS TOXIC BY ORAL ADMINISTRATION AS DEFINED IN 16 CFR 1500.

EYE CONTACT: THE EYES OF 2 RABBITS WERE FOUND TO SHOW EVIDENCE OF CONJUNCTIVAL CHANGES. IRRITATION SCORES IN INDIVIDUAL RABBITS RANGED FROM 0-2 (SCALE 0-110). THE MATERIAL IS NOT CLASSIFIED AS AN IRRITANT BY OCULAR APPLICATION AS DEFINED BY 16 CFR 1500.

SKIN CONTACT: THE PRIMARY IRRITATION INDEX WAS FOUND TO BE 1.3 (SCALE 0-8) BASED ON ERYTHEMA AND EDEMA. NO EVIDENCE OF TISSUE DAMAGE WAS FOUND. THE MATERIAL IS NOT CLASSIFIED AS A PRIMARY IRRITANT OR AS A CORROSIVE BY DERMAL APPLICATION AS DEFINED BY 16 CFR 1500.

EMERY MSDS
TESTING OF EMERY 3004 FOR COMEDOGENIC POTENTIAL (BLACKHEAD FORMATION) INDICATED THAT UNDER THE CONDITIONS OF THE STUDY, THE MATERIAL WAS NOT CONSIDERED TO SHOW COMEDOGENIC POTENTIAL.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: TWA: 5 MG/M3 (OIL MIST)

TLV: TWA: 5 MG/M3; STEL: 10 MG/M3 (OIL MIST)

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: DO NOT INDUCE VOMITING. IF VICTIM IS CONSCIOUS AND ABLE TO SWALLOW, PROMPTLY HAVE VICTIM DRINK WATER TO DILUTE. DO NOT GIVE SODIUM BICARBONATE, FRUIT JUICES OR VINEGAR. NEVER GIVE ANYTHING BY MOUTH IF THE VICTIM IS UNCONSCIOUS OR HAVING CONVULSIONS. **CALL A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY.**

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES.

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. **GET MEDICAL ATTENTION IMMEDIATELY.**

SECTION VI - PHYSICAL DATA

BOILING POINT: 754 DEG F (401 DEG C) ASTM D-86
VAPOR PRESSURE: <1 MM HG PRESSURE AT 20 DEG C
SPECIFIC GRAVITY: 0.819 AT 15.6/15.6 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
COLORLESS, ODORLESS FLUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 432 DEG F (222 DEG C) ASTM D-92
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT DETERMINED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT DETERMINED
NFPA RATING: NO NFPA RATING
HMIS RATING: HEALTH (0) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS
(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). USE WATER SPRAY, DRY CHEMICAL, FOAM OR CARBON DIOXIDE. WATER MAY BE INEFFECTIVE BUT SHOULD BE USED TO KEEP FIRE-EXPOSED CONTAINERS COOL. IF A SPILL OR LEAK HAS NOT IGNITED, USE WATER SPRAY TO DISPERSE THE VAPORS. WATER SPRAY MAY BE USED TO FLUSH SPILLS AWAY FROM FIRE.
UNUSUAL FIRE & EXPLOSION HAZARDS
FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID HEATING TO DECOMPOSITION. THE USER IS ADVISED TO HAVE A SAFETY EXPERT EVALUATE THE SPECIFIC CONDITIONS OF USE.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
WHERE EXPOSURE IS LIKELY TO EXCEED ACCEPTABLE CRITERIA (SEE SECTIONS II AND IV), USE NIOSH/OSHA APPROVED RESPIRATORY EQUIPMENT. RESPIRATORS SHOULD BE SELECTED BASED ON THE FORM AND CONCENTRATION OF CONTAMINANT IN AIR AND IN ACCORDANCE WITH OSHA (29 CFR 1910.134).
PROTECTIVE CLOTHING:
WEAR GLOVES AND PROTECTIVE CLOTHING WHICH ARE IMPERVIOUS TO THE PRODUCT FOR THE DURATION OF ANTICIPATED EXPOSURE IF THERE IS POTENTIAL FOR PROLONGED OR REPEATED SKIN CONTACT.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 3/31/89
SUPERSEDES: 11/2/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMERSOL 875 (3/9/90)

SECTION I - IDENTIFICATION

PRODUCT: EMERSOL 875 ISOSTEARIC ACID

SYNONYMS:

CHEMICAL: ALIPHATIC ACID

CAS NO: 30399-84-9

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
ISOSTEARIC ACID (30399-84-9)	70-76	NONE/NONE	NONE NOTED
ISOPALMITIC ACID (32844-67-0)	6-7	NONE/NONE	NONE NOTED
MYRISTIC ACID (544-63-8)	7-11	NONE/NONE	NONE NOTED
PALMITIC ACID (57-10-3)	4-5	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: LD50:>32 ML/KG (ALBINO RATS)

EYE CONTACT: ISOSTEARIC ACID MAY CAUSE MINIMAL EYE IRRITATION BASED ON RABBIT EYE IRRITATION STUDIES.

SKIN CONTACT: INSULT PATCH TEST ON 23 FEMALES CAUSED LITTLE OR NO CUTANEOUS IRRITATION OR CONTACT SENSITIZATION.

PRIMARY IRRITATION INDEX WAS 0.63 ON A DRAIZE SCALE OF 0-8.0.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: CALL A PHYSICIAN OR POISON CONTROL CENTER PROMPTLY.

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES. GET MEDICAL ATTENTION IMMEDIATELY.

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. GET MEDICAL ATTENTION IMMEDIATELY.

SECTION VI - PHYSICAL DATA

BOILING POINT: 356-410 DEG F (180-210 DEG C) AT 4MM HG PRESSURE
MELTING POINT: 12 DEG C (APPROX.)
VAPOR PRESSURE: 50 MM HG PRESSURE AT 265 DEG C
SPECIFIC GRAVITY: 0.89 AT 75/25 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
LIGHT YELLOW LIQUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 360 DEG F (182 DEG C) OPEN CUP
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT ESTABLISHED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT ESTABLISHED
NFPA RATING: HEALTH (1) FIRE (1) REACTIVITY (0) (STEARIC ACID)
HMIS RATING: HEALTH (1) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS

(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). WATER OR FOAM MAY CAUSE FROTHING WHEN APPLIED TO FLAMMABLE LIQUIDS HAVING FLASH POINTS ABOVE 212 DEG F (100 DEG C). THE REMARK IS INCLUDED ONLY AS A PRECAUTION AND DOES NOT MEAN THAT WATER OR FOAM SHOULD NOT OR COULD NOT BE USED IN FIGHTING FIRES IN SUCH LIQUIDS. THE FROTHING MAY BE QUITE VIOLENT AND COULD ENDANGER THE LIFE OF THE FIREFIGHTER PARTICULARLY WHEN SOLID STREAMS ARE DIRECTED INTO THE HOT BURNING LIQUID. ON THE OTHER HAND, WATER SPRAY CAREFULLY APPLIED HAS FREQUENTLY BEEN USED WITH SUCCESS IN EXTINGUISHING SUCH FIRES BY CAUSING THE FROTHING TO OCCUR ONLY ON THE SURFACE AND THIS FOAMING ACTION BLANKETS AND EXTINGUISHES THE FIRE. (NFPA 325M-1984)

UNUSUAL FIRE & EXPLOSION HAZARDS

FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

BILITY:
GENERALLY STABLE
ARDOUS POLYMERIZATION:
NONE LIKELY
DITIONS & MATERIALS TO AVOID:
AVOID CONTACT WITH STRONG OXIDIZING AGENTS AND STRONG ALKALIES.
ARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

TROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
PIRATORY PROTECTION:
RECOMMENDED EXPOSURE LIMITS (i.e., OSHA-PEL AND ACGIH-TLV) HAVE NOT BEEN ESTABLISHED FOR THIS MATERIAL. WHETHER THERE IS A NEED FOR RESPIRATORY PROTECTION UNDER YOUR CONDITIONS OF HANDLING OF THIS MATERIAL SHOULD BE EVALUATED BY A QUALIFIED HEALTH SPECIALIST.
TECTIVE CLOTHING:
NO NEED ANTICIPATED.
: PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

IRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
LL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
STE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

KEEP IN CLOSED OR COVERED CONTAINERS AND DO NOT STORE NEAR HEAT OR OPEN FLAMES TO PRESERVE THE COLOR AND ODOR CHARACTERISTICS OF THIS PRODUCT.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 3/9/90
SUPERSEDES: 10/19/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 **CHEMTREC** 800-424-9300

MSDS REFERENCE: EMERSOL 871 (1/2/90)

SECTION I - IDENTIFICATION

PRODUCT: EMERSOL 871 ISOSTEARIC ACID

SYNONYMS:

CHEMICAL: ALIPHATIC ACID

CAS NO: 30399-84-9

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
ISOSTEARIC ACID (30399-84-9)	60-66	NONE/NONE	NONE NOTED
ISOOLEIC ACID	13-17	NONE/NONE	NONE NOTED
ISOPALMITIC ACID (32844-67-0)	1-3	NONE/NONE	NONE NOTED
STEARIC ACID (57-11-4)	8-10	NONE/NONE	NONE NOTED
OLEIC ACID (112-80-1)	6-12	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: LD50:>32 ML/KG (ALBINO RATS)

EYE CONTACT: ISOSTEARIC ACID MAY CAUSE MINIMAL EYE IRRITATION BASED ON RABBIT EYE IRRITATION STUDIES.

SKIN CONTACT: INSULT PATCH TEST ON 23 FEMALES CAUSED LITTLE OR NO CUTANEOUS IRRITATION OR CONTACT SENSITIZATION (SIMILAR PRODUCT).

PRIMARY IRRITATION INDEX WAS 0.0-0.5.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: **CALL A PHYSICIAN OR POISON CONTROL CENTER PROMPTLY.**

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES. **GET MEDICAL ATTENTION IMMEDIATELY.**

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. **GET MEDICAL ATTENTION IMMEDIATELY.**

SECTION VI - PHYSICAL DATA

BOILING POINT: 356-410 DEG F (180-210 DEG C) AT 4MM HG PRESSURE
MELTING POINT: 15 DEG C (APPROX.)
VAPOR PRESSURE: 50 MM HG PRESSURE AT 265 DEG C
SPECIFIC GRAVITY: 0.86 AT 75/25 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
LIGHT YELLOW LIQUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 360 DEG F (182 DEG C) OPEN CUP
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT ESTABLISHED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT ESTABLISHED
NFPA RATING: HEALTH (1) FIRE (1) REACTIVITY (0) (STEARIC ACID)
HMIS RATING: HEALTH (1) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS

(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). WATER OR FOAM MAY CAUSE FROTHING WHEN APPLIED TO FLAMMABLE LIQUIDS HAVING FLASH POINTS ABOVE 212 DEG F (100 DEG C). THE REMARK IS INCLUDED ONLY AS A PRECAUTION AND DOES NOT MEAN THAT WATER OR FOAM SHOULD NOT OR COULD NOT BE USED IN FIGHTING FIRES IN SUCH LIQUIDS. THE FROTHING MAY BE QUITE VIOLENT AND COULD ENDANGER THE LIFE OF THE FIREFIGHTER PARTICULARLY WHEN SOLID STREAMS ARE DIRECTED INTO THE HOT BURNING LIQUID. ON THE OTHER HAND, WATER SPRAY CAREFULLY APPLIED HAS FREQUENTLY BEEN USED WITH SUCCESS IN EXTINGUISHING SUCH FIRES BY CAUSING THE FROTHING TO OCCUR ONLY ON THE SURFACE AND THIS FOAMING ACTION BLANKETS AND EXTINGUISHES THE FIRE. (NFPA 325M-1984)

UNUSUAL FIRE & EXPLOSION HAZARDS

FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID CONTACT WITH STRONG OXIDIZING AGENTS AND STRONG ALKALIES.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
RECOMMENDED EXPOSURE LIMITS (i.e., OSHA-PEL AND ACGIH-TLV) HAVE NOT BEEN ESTABLISHED FOR THIS MATERIAL. WHETHER THERE IS A NEED FOR RESPIRATORY PROTECTION UNDER YOUR CONDITIONS OF HANDLING OF THIS MATERIAL SHOULD BE EVALUATED BY A QUALIFIED HEALTH SPECIALIST.
PROTECTIVE CLOTHING:
NO NEED ANTICIPATED.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

KEEP IN CLOSED OR COVERED CONTAINERS AND DO NOT STORE NEAR HEAT OR OPEN FLAMES TO PRESERVE THE COLOR AND ODOR CHARACTERISTICS OF THIS PRODUCT.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 1/2/90
SUPERSEDES: 10/19/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

EMERY CHEMICALS

DIVISION OF NATIONAL DISTILLERS AND CHEMICAL CORPORATION

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMERY 3002 (2/25/87)

SECTION I - IDENTIFICATION

PRODUCT: EMERY 3002 SYNTHETIC HYDROCARBON 2 CST FLUID

SYNONYMS: POLYALPHAOLEFIN

CHEMICAL: SYNTHETIC ALIPHATIC HYDROCARBON

CAS NO: 68649-11-6

SECTION II - HAZARDOUS INGREDIENTS

COMPOSITION	%	PEL/TLV	HAZARD
POLYALPHAOLEFIN (68649-11-6)	100	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: UNKNOWN

EYE CONTACT: A PRODUCT CONTAINING MORE THAN 50% POLYALPHAOLEFINS WAS NOT CLASSIFIED AS AN IRRITANT BY OCULAR APPLICATION.

SKIN CONTACT: A PRODUCT CONTAINING MORE THAN 50% POLYALPHAOLEFINS WAS NOT CLASSIFIED AS A PRIMARY IRRITANT OR AS A CORROSIVE BY DERMAL APPLICATION.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: DO NOT INDUCE VOMITING. IF VICTIM IS CONSCIOUS AND ABLE TO SWALLOW, PROMPTLY HAVE VICTIM DRINK WATER TO DILUTE. DO NOT GIVE SODIUM BICARBONATE, FRUIT JUICES OR VINEGAR. NEVER GIVE ANYTHING BY MOUTH IF THE VICTIM IS UNCONSCIOUS OR HAVING CONVULSIONS. CALL A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY.

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES.

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. GET MEDICAL ATTENTION IMMEDIATELY.

SECTION VI - PHYSICAL DATA

BOILING POINT: INITIAL BOILING POINT 310 DEG C (ASTM D-1078)
VAPOR PRESSURE: <1 MM HG PRESSURE AT 20 DEG C
SPECIFIC GRAVITY: 0.790 AT 15.6/15.6 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
COLORLESS, ODORLESS FLUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 320 DEG F (160 DEG C) ASTM D-92
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT DETERMINED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT DETERMINED
NFPA RATING: NO NFPA RATING
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS
(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). USE WATER SPRAY, DRY CHEMICAL, FOAM OR CARBON DIOXIDE. WATER MAY BE INEFFECTIVE BUT SHOULD BE USED TO KEEP FIRE-EXPOSED CONTAINERS COOL. IF A SPILL OR LEAK HAS NOT IGNITED, USE WATER SPRAY TO DISPERSE THE VAPORS. WATER SPRAY MAY BE USED TO FLUSH SPILLS AWAY FROM FIRE.
UNUSUAL FIRE & EXPLOSION HAZARDS
FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID HEATING TO DECOMPOSITION. THE USER IS ADVISED TO HAVE A SAFETY EXPERT EVALUATE THE SPECIFIC CONDITIONS OF USE.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION OF ORGANIC MATERIALS MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
WHERE EXPOSURE IS LIKELY TO EXCEED ACCEPTABLE CRITERIA (SEE SECTIONS II AND IV), USE NIOSH/OSHA APPROVED RESPIRATORY EQUIPMENT. RESPIRATORS SHOULD BE SELECTED BASED ON THE FORM AND CONCENTRATION OF CONTAMINANT IN AIR AND IN ACCORDANCE WITH OSHA (29 CFR 1910.134).
PROTECTIVE CLOTHING:
WEAR GLOVES AND PROTECTIVE CLOTHING WHICH ARE IMPERVIOUS TO THE PRODUCT FOR THE DURATION OF ANTICIPATED EXPOSURE IF THERE IS POTENTIAL FOR PROLONGED OR REPEATED SKIN CONTACT.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which National Distillers and Chemical Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: IRWIN S. SCHLOSSMAN

DATE: 2/25/87
SUPERSEDES: 11/13/86

Emery Chemicals
4900 Este Avenue
Cincinnati, Ohio 45232

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMERY 3006 (9/26/89)

SECTION I - IDENTIFICATION

PRODUCT: EMERY 3006 SYNTHETIC HYDROCARBON 6 CST FLUID

SYNONYMS: POLYALPHAOLEFIN

CHEMICAL: SYNTHETIC ALIPHATIC HYDROCARBON

CAS NO: 68037-01-4

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
POLYALPHAOLEFIN (68037-01-4)	100	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: THE ESTIMATED LC50 FOR A 1 HOUR EXPOSURE TO 2 CST PAO WAS 4.68 MG/L (RATS), WHICH IS CONSIDERED TOXIC. IN ORDER TO DETERMINE THE LC50 VALUE, EXTREMELY HEAVY MISTS OF PAO WERE REQUIRED. THE VERY HEAVY MISTS AT THE NECESSARY CONCENTRATION MADE VISIBILITY DIFFICULT AND WOULD BE DIFFICULT TO WORK IN FOR ANY PERIOD OF TIME. THE AUTHOR REPORTED THAT HISTOPATHOLOGICAL CHANGES MAY HAVE BEEN A RESPONSE TO A PHYSICAL INSULT RATHER THAN A SPECIFIC COMPOUND RELATED TOXICITY EFFECT AND THAT 2 CST PAO MAY BE CONSIDERED NON-HAZARDOUS FOR ALL PRACTICAL PURPOSES BY INHALATION.

INGESTION: THE ACUTE ORAL LD50 VALUE WAS FOUND TO BE GREATER THAN 5.0 G/KG IN MALE AND FEMALE SPRAGUE-DAWLEY RATS. THE MATERIAL IS NOT CLASSIFIED AS TOXIC BY ORAL ADMINISTRATION AS DEFI[illegible] IN 16 CFR 1500.

EYE CONTACT: THE EYES OF 5 RABBITS WERE FOUND TO SHOW EVIDENCE OF CONJUNCTIVAL CHANGES. IRRITATION SCORES IN INDIVIDUAL RABBITS RANGED FROM 0-4 (SCALE 0-110). THE MATERIAL IS NOT CLASSIFIED AS AN IRRITANT BY OCULAR APPLICATION AS DEFINED BY 16 CFR 1500.

SKIN CONTACT: THE PRIMARY IRRITATION INDEX WAS FOUND TO BE 0.5 (SCALE 0-8) BASED ON ERYTHEMA AND EDEMA. NO EVIDENCE OF TISSUE DAMAGE WAS FOUND. THE MATERIAL IS NOT CLASSIFIED AS A PRIMARY IRRITANT OR AS A CORROSIVE BY DERMAL APPLICATION AS DEFINED BY 16 CFR 1500. UNDER THE CONDITIONS OF A COMEDOGENICITY STUDY, EMERY 3006 DOES NOT APPEAR TO HAVE A COMEDOGENIC POTENTIAL.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: TWA: 5 MG/M3 (OIL MIST)

TLV: TWA: 5MG/M3; STEL: 10 MG/M3 (OIL MIST)

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: DO NOT INDUCE VOMITING. IF VICTIM IS CONSCIOUS AND ABLE TO SWALLOW, PROMPTLY HAVE VICTIM DRINK WATER TO DILUTE. DO NOT GIVE SODIUM BICARBONATE, FRUIT JUICES OR VINEGAR. NEVER GIVE ANYTHING BY MOUTH IF THE VICTIM IS UNCONSCIOUS OR HAVING CONVULSIONS. CALL A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY.

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES.

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. GET MEDICAL ATTENTION IMMEDIATELY.

SECTION VI - PHYSICAL DATA

BOILING POINT: 781 DEG F (416 DEG C) ASTM D-86
VAPOR PRESSURE: <1 MM HG PRESSURE AT 20 DEG C
SPECIFIC GRAVITY: 0.828 AT 15.6/15.6 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
COLORLESS, ODORLESS FLUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 464 DEG F (240 DEG C) ASTM D-92
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT DETERMINED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT DETERMINED
NFPA RATING: NO NFPA RATING
HMIS RATING: HEALTH (0) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS
(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). USE WATER SPRAY, DRY CHEMICAL, FOAM OR CARBON DIOXIDE. WATER MAY BE INEFFECTIVE BUT SHOULD BE USED TO KEEP FIRE-EXPOSED CONTAINERS COOL. IF A SPILL OR LEAK HAS NOT IGNITED, USE WATER SPRAY TO DISPERSE THE VAPORS. WATER SPRAY MAY BE USED TO FLUSH SPILLS AWAY FROM FIRE.

UNUSUAL FIRE & EXPLOSION HAZARDS
FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID HEATING TO DECOMPOSITION. THE USER IS ADVISED TO HAVE A SAFETY EXPERT EVALUATE THE SPECIFIC CONDITIONS OF USE.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
WHERE EXPOSURE IS LIKELY TO EXCEED ACCEPTABLE CRITERIA (SEE SECTIONS II AND IV), USE NIOSH/OSHA APPROVED RESPIRATORY EQUIPMENT. RESPIRATORS SHOULD BE SELECTED BASED ON THE FORM AND CONCENTRATION OF CONTAMINANT IN AIR AND IN ACCORDANCE WITH OSHA (29 CFR 1910.134).
PROTECTIVE CLOTHING:
WEAR GLOVES AND PROTECTIVE CLOTHING WHICH ARE IMPERVIOUS TO THE PRODUCT FOR THE DURATION OF ANTICIPATED EXPOSURE IF THERE IS POTENTIAL FOR PROLONGED OR REPEATED SKIN CONTACT.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 9/26/89
SUPERSEDES: 11/2/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

APPENDIX A

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMERY 2219 (6/6/89)

SECTION I - IDENTIFICATION

PRODUCT: EMERY 2219 METHYL OLEATE

SYNONYMS: METHYL 9-OCTADECENOATE; 9-OCTADECENOIC ACID, METHYL ESTER

CHEMICAL: METHYL ESTER

CAS NO: 112-62-9

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
METHYL OLEATE (112-62-9)	58	NONE/NONE	NONE NOTED
METHYL STEARATE (112-61-8)	24	NONE/NONE	NONE NOTED
METHYL LINOLEATE (112-63-0)	14	NONE/NONE	NONE NOTED
METHYL PALMITATE (112-39-0)	4	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: LD50:>50 ML/KG (ALBINO RATS)

EYE CONTACT: SIMILAR PRODUCTS WERE NOT CLASSIFIED AS EYE IRRITANTS.

SKIN CONTACT: SIMILAR PRODUCTS WERE NOT CLASSIFIED AS PRIMARY SKIN IRRITANTS OF CORROSIVE AGENTS.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: **CALL A PHYSICIAN OR POISON CONTROL CENTER PROMPTLY.**

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES.

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. **GET MEDICAL ATTENTION IMMEDIATELY.**

SECTION VI - PHYSICAL DATA

BOILING POINT: 316 DEG F (158 DEG C) AT 1 MM HG PRESSURE
MELTING POINT: 64 DEG F (18 DEG C)
VAPOR PRESSURE: APPROX. 10 MM HG PRESSURE AT 205 DEG C
SPECIFIC GRAVITY: 0.88 AT 25 DEG C
SOLUBILITY IN WATER: NEGLIGIBLE AT ROOM TEMPERATURE
APPEARANCE AND COLOR:
LIGHT YELLOW LIQUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 345 DEG F (173 DEG C) (OPEN CUP)
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT ESTABLISHED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT ESTABLISHED
NFPA RATING: NO NFPA RATING
HMIS RATING: HEALTH (0) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS
(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). USE WATER SPRAY, DRY CHEMICAL, FOAM OR CARBON DIOXIDE. WATER MAY BE INEFFECTIVE BUT SHOULD BE USED TO KEEP FIRE-EXPOSED CONTAINERS COOL. IF A SPILL OR LEAK HAS NOT IGNITED, USE WATER SPRAY TO DISPERSE THE VAPORS. WATER SPRAY MAY BE USED TO FLUSH SPILLS AWAY FROM FIRE.
UNUSUAL FIRE & EXPLOSION HAZARDS
FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID CONTACT WITH STRONG OXIDIZING AGENTS
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
RECOMMENDED EXPOSURE LIMITS (i.e., OSHA-PEL AND ACGIH-TLV) HAVE NOT BEEN ESTABLISHED FOR THIS MATERIAL. WHETHER THERE IS A NEED FOR RESPIRATORY PROTECTION UNDER YOUR CONDITIONS OF HANDLING OF THIS MATERIAL SHOULD BE EVALUATED BY A QUALIFIED HEALTH SPECIALIST.
PROTECTIVE CLOTHING:
NO NEED ANTICIPATED.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 6/6/89
SUPERSEDES: 2/13/89

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

W I T C O   M A T E R I A L   S A F E T Y   D A T A   S H E E T

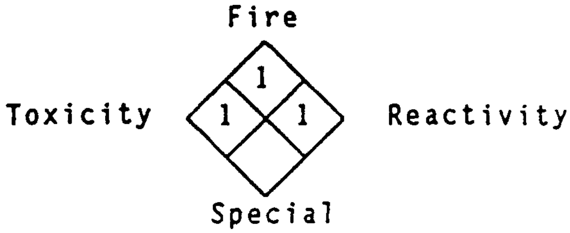
INDUSTRENE(R)206LP

Product Code: 170 0315

CAS NO:112-80-1

HAZARD RATING

N 4 - Extreme
F 3 - High
P 2 - Moderate
A 1 - Slight
0 - Insignificant



DIVISION AND LOCATION---SECTION I

Division: HUMKO
Location: MEMPHIS, TN
P.O. BOX 125,1231 POPE STREET,MEMPHIS,TN,38101108
Emergency Telephone Number: (901) 320-5800
Transportation Emergency: CHEM TREC 1-(800) 424-9300 (U.S. and Canada)

CHEMICAL AND PHYSICAL PROPERTIES---SECTION II

Chemical Name:
oleic fatty acid
Formula: Mixture
Hazardous Decomposition Products:
carbon monoxide and carbon dioxide from burning.
Incompatibility (Keep away from):
strong oxidizers such as hydrogen peroxide, bromine, and chromic acid.
Toxic and Hazardous Ingredients:
none
Form: liquid   Odor: mild - typically fatty.
Appearance: waxy,oily   Color: light yellow
Specific Gravity (water=1): approximately .875
Boiling Point: greater than 260°C (500°F)
Melting Point: approximately 11 to 14°C (52 to 57°F)
Solubility in Water (by weight %): negligable
Volatile (by weight %): negligible
Evaporation Rate: negligible
Vapor Pressure (mm Hg at 20°C): negligable
Vapor Density (air=1): not applicable
pH (as is): no data available
Stability: Product is stable under normal conditions
Viscosity SUS at 100°F: Less than 100

FIRE AND EXPLOSION DATA---SECTION III

Special Fire Fighting Procedures:
Do not use heavy stream of water. Fatty material will float.
Unusual Fire and Explosion Hazards:
none
Flashpoint: (Method Used) Pensky-Martens Open Cup approximately 193°C (380°F)

(Continued on next page)

Product Code: 170 0315

(Section III continued)

Flammable limits %: no data available

Extinguishing agents:

Drychemical or Waterspray or Waterfog or CO_2 or Foam or Sand/Earth
Exposed material may be cooled with water.

HEALTH HAZARD DATA---SECTION IV

Permissible concentrations (air):

no data available

Chronic effects of overexposure:

no data available

Acute toxicological properties:

acute oral LD_{50} greater than 20 ml/kg (rat)

Emergency First Aid Procedures:

Eyes: Immediately flush with large quantities of water for at least 15 minutes and call a physician.

Skin Contact: Wash with soap and water. For contact with hot molten material, cool burned skin area by immersing in cold water or apply cold water.

Inhalation: Remove victim to fresh air.

If Swallowed: Contact a physician immediately.

SPECIAL PROTECTION INFORMATION---SECTION V

Ventilation Type Required (Local,mechanical,special):

Local if necessary to control dust or fumes from hot material and to maintain the permissible exposure limit (pel) or threshold limit value (TLV)

Respiratory Protection (Specify type):

Use NIOSH/OSHA approved dust mask and/or respirator where appropriate.

Protective Gloves: neoprene type

Eye Protection: chemical safety goggles.

Other Protective Equipment:

neoprene protective type apron.

HANDLING OF SPILLS OR LEAKS---SECTION VI

Procedures for Clean-Up:

Ordinary housekeeping procedures are adequate. Melted material can cause thermal burns. Can be burned or landfilled.

Waste Disposal:

Dispose of in accordance with all applicable federal, state and local regulations.

(Continued on next page)

Product Code: 170 0315

SPECIAL PRECAUTIONS---SECTION VII

Precautions to be taken in handling and storage:
Keep containers sealed until ready for use. Avoid excessive long term storage temperatures to prolong shelf life.
Maximum Storage Temperature: 52°C (125°F)

TRANSPORTATION DATA---SECTION VIII

D.O.T.: Not Regulated
Reportable Quantity: not applicable
Freight Classification: fatty acids of animal oil
Special Transportation Notes:

COMMENTS---SECTION IX

For Industrial Use Only.

Signature: BRUCE MOORMAN Bruce Moorman
Title:
REGULATORY COMPLIANCE
Original Date: 01/01/84 Sent to: Date:
Revision Date: 11/06/85
Supersedes: 01/01/84

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMERSOL 233 (12/12/89)

SECTION I - IDENTIFICATION

PRODUCT: EMERSOL 233 LL OLEIC ACID

SYNONYMS: 9-OCTADECENOIC ACID

CHEMICAL: UNSATURATED ALIPHATIC CARBOXYLIC ACID

CAS NO: 112-80-1

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
OLEIC ACID (112-80-1)	74	NONE/NONE	NONE NOTED
PALMITOLEIC ACID (2091-29-4)	11	NONE/NONE	NONE NOTED
LINOLEIC ACID (60-33-3)	4	NONE/NONE	NONE NOTED
MYRISTOLEIC ACID (544-64-9)	3	NONE/NONE	NONE NOTED
SATURATED ACIDS (*)	8	NONE/NONE	NONE NOTED

(*) C14-C17 CARBOXYLIC ACIDS

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: LD50:>21.5 ML/KG (MALE ALBINO RATS)

EYE CONTACT: THE MATERIAL PRODUCED MILD CONJUNCTIVITIS IN FIVE OF SIX RABBITS. NO OTHER IRRITATIVE SIGNS WERE OBSERVED AND ALL EXCEPT ONE RABBIT SHOWED NO IRRITATIVE SIGNS AT THE 72-HOUR READING.

SKIN CONTACT: THE MATERIAL PRODUCED VERY SLIGHT ERYTHEMA IN SIX INTACT AND SIX ABRADED SITES ON ALBINO RABBITS AT THE 24-HOUR READING ONLY. NO EDEMA WAS OBSERVED AT EITHER READING.

PRIMARY IRRITATION INDEX WAS CALCULATED TO BE 0.50.

15 MG OF OLEIC ACID INTERMITTENTLY APPLIED TO HUMAN SKIN OVER A 3-DAY PERIOD RESULTED IN MODERATE IRRITATION. 500 MG OF OLEIC ACID APPLIED TO RABBIT SKIN IN AN OPEN DRAIZE TEST RESULTED IN MILD IRRITATION.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: **CALL A PHYSICIAN OR POISON CONTROL CENTER PROMPTLY.**

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES. **GET MEDICAL ATTENTION IMMEDIATELY.**

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. **GET MEDICAL ATTENTION IMMEDIATELY.**

SECTION VI - PHYSICAL DATA

BOILING POINT: 547 DEG F (286 DEG C) AT 100 MM HG PRESSURE (APPROX.)
MELTING POINT: 14 DEG C (APPROX.)
VAPOR PRESSURE: 10 MM HG PRESSURE AT 224 DEG C
SPECIFIC GRAVITY: 0.891 AT 25/20 DEG C
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
LIGHT COLOR-LIQUID WITH A FATTY ACID ODOR

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 364-372 DEG F (184-189 DEG C) CLOSED CUP
AUTO-IGNITION TEMPERATURE: 685 DEG F (363 DEG C)
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT ESTABLISHED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT ESTABLISHED
NFPA RATING: HEALTH (0) FIRE (1) REACTIVITY (0) FOR OLEIC ACID
HMIS RATING: HEALTH (0) FIRE (1) REACTIVITY (0) FOR OLEIC ACID
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS

(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). WATER OR FOAM MAY CAUSE FROTHING WHEN APPLIED TO FLAMMABLE LIQUIDS HAVING FLASH POINTS ABOVE 212 DEG F (100 DEG C). THE REMARK IS INCLUDED ONLY AS A PRECAUTION AND DOES NOT MEAN THAT WATER OR FOAM SHOULD NOT OR COULD NOT BE USED IN FIGHTING FIRES IN SUCH LIQUIDS. THE FROTHING MAY BE QUITE VIOLENT AND COULD ENDANGER THE LIFE OF THE FIREFIGHTER PARTICULARLY WHEN SOLID STREAMS ARE DIRECTED INTO THE HOT BURNING LIQUID. ON THE OTHER HAND, WATER SPRAY CAREFULLY APPLIED HAS FREQUENTLY BEEN USED WITH SUCCESS IN EXTINGUISHING SUCH FIRES BY CAUSING THE FROTHING TO OCCUR ONLY ON THE SURFACE AND THIS FOAMING ACTION BLANKETS AND EXTINGUISHES THE FIRE. (NFPA 325M-1984)

UNUSUAL FIRE & EXPLOSION HAZARDS
FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
AVOID CONTACT WITH STRONG OXIDIZING AGENTS AND STRONG ALKALIES.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE CARBON MONOXIDE AND CARBON DIOXIDE.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
RECOMMENDED EXPOSURE LIMITS (i.e., OSHA-PEL AND ACGIH-TLV) HAVE NOT BEEN ESTABLISHED FOR THIS MATERIAL. WHETHER THERE IS A NEED FOR RESPIRATORY PROTECTION UNDER YOUR CONDITIONS OF HANDLING OF THIS MATERIAL SHOULD BE EVALUATED BY A QUALIFIED HEALTH SPECIALIST.
PROTECTIVE CLOTHING:
WEAR GLOVES AND PROTECTIVE CLOTHING WHICH ARE IMPERVIOUS TO THE PRODUCT FOR THE DURATION OF ANTICIPATED EXPOSURE IF THERE IS POTENTIAL FOR PROLONGED OR REPEATED SKIN CONTACT.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1 WHERE NO CONTACT WITH THE EYE IS ANTICIPATED. CHEMICAL SAFETY GOGGLES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1 SHOULD BE WORN WHENEVER THERE IS THE POSSIBILITY OF SPLASHING OR OTHER CONTACT WITH THE EYES.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY.

KEEP IN CLOSED OR COVERED CONTAINERS AND DO NOT STORE NEAR HEAT OR OPEN FLAMES TO PRESERVE THE COLOR AND ODOR CHARACTERISTICS OF THE PRODUCT.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 12/12/89
SUPERSEDES: 9/9/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

HENKEL CORPORATION

EMERY GROUP

Material Safety Data Sheet

EMERGENCY PHONE: (513) 482-2297 CHEMTREC 800-424-9300

MSDS REFERENCE: EMEREST 2310 (12/5/89)

SECTION I - IDENTIFICATION

PRODUCT: EMEREST 2310 ISOPROPYL ISOSTEARATE

SYNONYMS: ISOSTEARIC ACID, 2-PROPYL ESTER

CHEMICAL: ESTER

CAS NO: 68171-33-5

SARA HAZARD: NONE NOTED (SECTION 311/312)
TITLE III SECTION 313- NOT LISTED

SECTION II - INGREDIENTS AND HAZARD CLASSIFICATION

COMPOSITION	%	PEL/TLV	HAZARD
ISOPROPYL ISOSTEARATE (68171-33-5)	99+	NONE/NONE	NONE NOTED

SECTION III - HEALTH INFORMATION

INHALATION: UNKNOWN

INGESTION: LD50:>64.0 CC/KG (ALBINO RATS)

EYE CONTACT: EYE IRRITATION WAS NOT OBSERVED WITH SIMILAR PRODUCTS.

SKIN CONTACT: A REPEATED INSULT PATCH TEST UNDER OCCLUSIVE PATCHES SHOWED THAT ISOPROPYL ISOSTEARATE CAUSED LITTLE OR NO IRRITATION. THERE WAS NO EVIDENCE OF SENSITIZATION.

SECTION IV - OCCUPATIONAL EXPOSURE LIMITS

PEL: NO OSHA PEL

TLV: NO ACGIH TLV

SECTION V - EMERGENCY FIRST AID PROCEDURE

FOR OVEREXPOSURE BY SWALLOWING: **CALL A PHYSICIAN OR POISON CONTROL CENTER PROMPTLY.**

FOR OVEREXPOSURE BY SKIN CONTACT: WASH AFFECTED AREA.

FOR OVEREXPOSURE BY EYE CONTACT: IMMEDIATELY FLUSH EYES WITH PLENTY OF COOL WATER FOR AT LEAST 15 MINUTES. DO NOT LET VICTIM RUB EYES. **GET MEDICAL ATTENTION IMMEDIATELY.**

FOR OVEREXPOSURE BY INHALATION: IMMEDIATELY REMOVE VICTIM TO FRESH AIR. IF VICTIM HAS STOPPED BREATHING GIVE ARTIFICIAL RESPIRATION, PREFERABLY BY MOUTH-TO-MOUTH. **GET MEDICAL ATTENTION IMMEDIATELY.**

SECTION VI - PHYSICAL DATA

BOILING POINT: NOT DETERMINED
MELTING POINT: LIQUID AT ROOM TEMPERATURE
VAPOR PRESSURE: NOT ESTABLISHED
SPECIFIC GRAVITY: 0.858 AT 25/25 DEG C
VAPOR DENSITY (AIR=1): GREATER THAN 1
SOLUBILITY IN WATER: INSOLUBLE
APPEARANCE AND COLOR:
CLEAR, LIGHT YELLOW LIQUID

SECTION VII - FIRE AND EXPLOSION HAZARDS

FLASH POINT & METHOD USED: 345 DEG F (174 DEG C) C.O.C.
FLAMMABLE LIMITS IN AIR, % BY VOL. LOWER: NOT ESTABLISHED
FLAMMABLE LIMITS IN AIR, % BY VOL. UPPER: NOT ESTABLISHED
NFPA RATING: NO NFPA RATING
HMIS RATING: HEALTH (0) FIRE (1) REACTIVITY (0)
SPECIAL FIRE FIGHTING PROCEDURES & PRECAUTIONS

(INDIVIDUALS SHOULD PERFORM ONLY THOSE FIRE FIGHTING PROCEDURES FOR WHICH THEY HAVE BEEN TRAINED). WATER OR FOAM MAY CAUSE FROTHING WHEN APPLIED TO FLAMMABLE LIQUIDS HAVING FLASH POINTS ABOVE 212 DEG F (100 DEG C). THE REMARK IS INCLUDED ONLY AS A PRECAUTION AND DOES NOT MEAN THAT WATER OR FOAM SHOULD NOT OR COULD NOT BE USED IN FIGHTING FIRES IN SUCH LIQUIDS. THE FROTHING MAY BE QUITE VIOLENT AND COULD ENDANGER THE LIFE OF THE FIREFIGHTER PARTICULARLY WHEN SOLID STREAMS ARE DIRECTED INTO THE HOT BURNING LIQUID. ON THE OTHER HAND, WATER SPRAY CAREFULLY APPLIED HAS FREQUENTLY BEEN USED WITH SUCCESS IN EXTINGUISHING SUCH FIRES BY CAUSING THE FROTHING TO OCCUR ONLY ON THE SURFACE AND THIS FOAMING ACTION BLANKETS AND EXTINGUISHES THE FIRE. (NFPA 325M-1984)

UNUSUAL FIRE & EXPLOSION HAZARDS

FIREFIGHTERS SHOULD WEAR SELF-CONTAINED BREATHING APPARATUS IN THE POSITIVE-PRESSURE MODE WITH A FULL FACEPIECE WHEN THERE IS A POSSIBILITY OF EXPOSURE TO SMOKE, FUMES OR HAZARDOUS DECOMPOSITION PRODUCTS.

SECTION VIII - REACTIVITY

STABILITY:
GENERALLY STABLE
HAZARDOUS POLYMERIZATION:
NONE LIKELY
CONDITIONS & MATERIALS TO AVOID:
KEEP AWAY FROM HEAT AND FLAMES. AVOID CONTACT WITH OXIDIZING MATERIALS.
HAZARDOUS DECOMPOSITION PRODUCTS:
DECOMPOSITION MAY PRODUCE OXIDES OF CARBON.

SECTION IX - EMPLOYEE PROTECTION

CONTROL MEASURES:
HANDLE IN THE PRESENCE OF ADEQUATE VENTILATION.
RESPIRATORY PROTECTION:
RECOMMENDED EXPOSURE LIMITS (I.E., OSHA-PEL AND ACGIH-TLV) HAVE NOT BEEN ESTABLISHED FOR THIS MATERIAL. WHETHER THERE IS A NEED FOR RESPIRATORY PROTECTION UNDER YOUR CONDITIONS OF HANDLING OF THIS MATERIAL SHOULD BE EVALUATED BY A QUALIFIED HEALTH SPECIALIST.
PROTECTIVE CLOTHING:
WEAR GLOVES AND PROTECTIVE CLOTHING WHICH ARE IMPERVIOUS TO THE PRODUCT FOR THE DURATION OF ANTICIPATED EXPOSURE IF THERE IS POTENTIAL FOR PROLONGED OR REPEATED SKIN CONTACT.
EYE PROTECTION:
WEAR SAFETY GLASSES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1 WHERE NO CONTACT WITH THE EYE IS ANTICIPATED. CHEMICAL SAFETY GOGGLES MEETING THE SPECIFICATIONS OF ANSI STANDARD Z87.1 SHOULD BE WORN WHENEVER THERE IS THE POSSIBILITY OF SPLASHING OR OTHER CONTACT WITH THE EYES.

SECTION X - ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PRECAUTIONS:
AVOID UNCONTROLLED RELEASES OF THIS MATERIAL. WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED.
SPILL OR LEAK PRECAUTIONS:
WEAR APPROPRIATE RESPIRATORY PROTECTION AND PROTECTIVE CLOTHING AS DESCRIBED IN SECTION IX. CONTAIN SPILLED MATERIAL. TRANSFER TO SECURE CONTAINERS. WHERE NECESSARY, COLLECT USING ABSORBENT MEDIA.
IN THE EVENT OF AN UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.
WASTE DISPOSAL:
ALL RECOVERED MATERIAL SHOULD BE PACKAGED, LABELED, TRANSPORTED, AND DISPOSED OR RECLAIMED IN CONFORMANCE WITH APPLICABLE LAWS AND REGULATIONS AND IN CONFORMANCE WITH GOOD ENGINEERING PRACTICES. AVOID LANDFILLING OF LIQUIDS. RECLAIM WHERE POSSIBLE.

SECTION XI - REGULATORY CONTROLS

DEPARTMENT OF TRANSPORTATION:
DOT CLASSIFICATION: NOT REGULATED
DOT PROPER SHIPPING NAME:
OTHER DOT INFORMATION:
OTHER REGULATORY REQUIREMENTS:
LISTED IN TSCA INVENTORY

SECTION XII - PRECAUTIONS: HANDLING, STORAGE AND USAGE

NO SPECIAL PRECAUTIONS NECESSARY. AVOID CONTAINER DAMAGE WHILE HANDLING AND STORING.

The information presented herein is believed to be factual as it has been derived from the works and opinions of persons believed to be qualified experts; however, nothing contained in this information is to be taken as a warranty or representation for which Henkel Corporation bears legal responsibility. The user should review any recommendations in the specific context of the intended use to determine whether they are appropriate.

PREPARED BY: ROBERT E. BORGERDING

DATE: 12/5/89
SUPERSEDES: 9/8/88

Henkel Corporation - Emery Group
4900 Este Avenue
Cincinnati, Ohio 45232

APPENDIX B

Properties of Poly-Alpha Olefins (PAOs),
Including "Emery 3004,"
and of Isostearic Acids
Emersol 871 and Emersol 875

Henkel

Henkel Corporation
Emery Group

EMERY 3004 PAO 4 cSt

Description

Emery's polyalphaolefin fluids are versatile, synthetic, hydrocarbon lubricant basestocks that can be used neat and are easily blended with petroleum oils or with other synthetic lubricant basestocks to produce lubricants for today's high performance needs.

Linear alpha olefins are polymerized and hydrogenated by state-of-the-art chemical technology to manufacture PAO's designed for use over a broad range of performance conditions, offering improved performance at both high and low operating temperatures.

Compared to conventional mineral oils and many synthetic lubricants, PAO-based lubricants exhibit low volatility and pour points, high flash and fire points, excellent thermal and oxidation stability, as well as compatibility with conventional mineral oils. Their high viscosity indices insure minimal viscosity changes with fluctuations in temperature and permit the formulation of full synthetic motor oils without viscosity index improvers. This results in fewer engine deposits, less sludge formation and varnish build-up, and eliminates viscosity changes due to shear down.

Emery's PAO fluids are available in bulk or 55 gallon steel non-returnable drums.

Applications

Emery's PAO fluids are recommended for use in the following applications:

- Partial and full synthetic engine oils, gear oils and power train lubricants to meet all SAE viscosity grades.
- U.S. Military Specifications, such as MIL-H-83282, MIL-H-46170, MIL-L-46167, MIL-G-81322 and MIL-L-63460B.
- Hydraulic fluids
- Electrical insulating fluids
- Compressor oils
- Stationary and marine turbine lubricants
- Greases
- Diluent for lubricant additives such as viscosity index improvers.

4900 Este Avenue, Cincinnati, Ohio 45232 Phone 513/482 2100

Typical Properties

Properties and Test Methods	3004 4cSt. PAO
Viscosity, cSt. (ASTM D-445)	
149°C	1.9
100°C	3.9
40°C	16.9
0°C	94.5
-40°C	2,520
Brookfield viscosity, 25°C, cP	34.5
Viscosity index (ASTM D-2270)	123
Moisture, ppm, (ASTM D-1774)	25
Pour Point, °C (ASTM D-97)	-69
Flash Point, °C (ASTM D-92)	219
Fire Point, °C (ASTM D-92)	249
Evaporation Loss, wt %, 6.5 hr @ 204.4°C (400°F) (ASTM D-972)	11
Color, Saybolt (ASTM D-156)	+30
Total acid number (ASTM D-974)	<0.03
Autoignition temperature, °C (ASTM D-2155)	343
Specific gravity, 15.6/15.6°C (ASTM D-1298)	0.819
Density, lbs./gal., 60°F	6.82

A Material Safety Data Sheet (MSDS) is available for this product. Users of this product are urged to study and use this information.

NGJ
9/90

Henkel

Emery Group

Henkel Corporation Emery Group

11501 Northlake Drive
P.O. Box 429557
Cincinnati, OH 45249
513-530-7300; Fax 513-530-7581

For Order Placement
Toll Free Number: 800-543-7370

Price List No. MG 70-09
Effective Date: April 15, 1991

PRICES SUBJECT TO CHANGE WITHOUT NOTICE
SEE REVERSE SIDE FOR SHIPPING INFORMATION

Polyalphaolefins		Product #	Bulk	TL 80 Drums	25-TL Drums	5-24 Drums	2-4 Drums	1 Drum	Net lbs./ Drum	Net lbs./ Gal.
*Emery® 4cSt	$/lb.	3004	POR	.86	.89	.93	.98	1.04	375	6.82
PAO	$/gal.		POR	5.87	6.07	6.34	6.86	7.09		
*Emery® 6cSt	$/lb.	3006	POR	.86	.89	0.93	.98	1.04	375	6.88
PAO	$/gal.		POR	5.92	6.12	6.40	6.74	7.16		
*Emery® 8cSt	$/lb.	3008	POR	.93	.96	1.00	1.05	1.11	375	6.91
PAO	$/gal.		POR	6.43	6.63	6.91	7.26	7.67		

*DENOTES CHANGE

Prices are $/pound, F.O.B. shipping point, minimum freight allowed in Continental U.S.
5 gallon pail — Add $1.00/lb. to Single Drum Price
Air freight or air express shipments F.O.B. shipping point.
Terms: Net 30 Days
GALLON PRICES: These prices are sometimes included on the price list for the convenience of our customers more accustomed to gallon pricing. All billing, invoicing, and shipping arrangements will be based on actual weight.

APPENDIX B

OVER, SHORT OR DAMAGED SHIPMENTS

Notation must be recorded on delivery record.

Contact Customer Service Center for detailed procedure.

BULK

Tankcars and Tanktrucks

A. Tankcar shipments are available in 8,000, 10,000 or 20,000 gallon quantities.

B. Standard for minimum tanktruck shipments is 40,000 pounds, however, maximum weights vary according to state and federal laws, normally 46,000 to 48,000 pounds net.

C. Tanktrucks will be shipped at tankcar prices where freight is comparable.

TRUCKLOADS

Standard for minimum truckload shipments is 80/88 drums (55 gallons), 24 supersacks or 880 bags (50 pounds net), except for products packaged in 25 kilogram bags which will be 800 bags, and 55 gallon drums of glycerine will be 72 drums.

OVERTIME CHARGES

SUNDAY/HOLIDAY LOADING CHARGE: Whenever Sunday/Holiday loading is required to meet requested delivery dates appropriate carrier's charges will be made.

DEFICIT FREIGHT

For less than standard minimum truckload and tanktruck quantities ordered and shipped by Emery, appropriate deficit freight charges, as determined by Emery, will be added to the invoice.

CUSTOMER PICKUPS

Specific pickup date will be agreed upon at the time of order placement. Loading of package goods will be restricted to the hours of 8 A.M. to 3 P.M. and bulk tanktruck loading **by appointment only**.
Non-compliance with the above requirements may result in considerable delay of customer's driver and equipment.

PICKUP ALLOWANCE

Pickup allowance will be based on the standard minimum truckload or tanktruck shipments freight rate, as determined by Emery, times the net weight and will be deducted from the invoice.

The minimum allowable tanktruck pickup will be 3,000 gallons.

Quantum

Emery® Polyalphaolefin Synthetic Lubricant Fluids

Technical Bulletin 108

Emery® Polyalphaolefins

Polyalphaolefin fluids are versatile, synthetic, hydrocarbon lubricant basestocks that can be used neat and are easily blended with petroleum oils or with other synthetic lubricant basestocks to produce lubricants for today's high performance needs.

Quantum Chemical Corporation now produces five primary unblended polyalphaolefin (PAO) synthetic lubricant fluids, offering you a line of 2, 4, 6, 8 and 10 centistoke viscosity grades to meet the rising demands of the synthetic lubricants market. These versatile, saturated, synthetic hydrocarbons, a result of direct oligomerization of decene-1, are an addition to Quantum's full line of diester and polyol ester basestocks. Emery® PAO's can be blended with other synthetic or petroleum basestocks to achieve the optimum balance of properties in lubricant formulations.

State of the Art Technology

At Quantum's Deer Park, Texas facility, linear alpha olefins are polymerized and hydrogenated by state of the art chemical technology to manufacture PAO's designed for use over a broad range of performance conditions, offering improved performance at both high and low operating temperatures.

Compared to conventional mineral oils and many synthetic lubricants, PAO-based lubricants exhibit low volatility and pour points, high flash and fire points, excellent thermal and oxidation stability, as well as compatibility with conventional mineral oils. Their high viscosity indices insure minimal viscosity changes with fluctuations in temperature and permit the formulation of full synthetic motor oils without viscosity index improvers. This results in fewer engine deposits, less sludge formation and varnish build-up, and eliminates viscosity changes due to shear-down.

Quantum's production facility in Deer Park, Texas utilizes state-of-the-art chemical technology to produce polyalphaolefins.

Meet FDA requirements

To further enhance their versatility, all five viscosity grades of Emery® PAO basestocks meet the FDA requirements which describe Synthetic Technical White Mineral Oils as related to their use as components of non-food articles intended for use in contact with food.

Applications

Emery PAO's are recommended for use in the following applications:

- Partial and full synthetic engine oils, gear oils and power train lubricants to meet all SAE viscosity grades.
- U.S. Military Specifications, such as MIL-H-83282, MIL-H-46170, MIL-L-46167, MIL-G-81322, and MIL-L-63460B.
- Hydraulic fluids
- Electrical insulating fluids.
- Meets requirements of USDA H-1 applications
- FDA Regulation 21 CFR 178.3620(b), for use as a Synthetic Technical White Mineral Oil for non-food articles in contact with food.
- Compressor oils
- Stationary and marine turbine lubricants.
- Greases
- Diluent for lubricant additives such as viscosity index improvers.

Technical Expertise

Quantum's Research and Development Staff, with expertise in application technology for both PAO and ester based lubricants, is available to help meet your formulation needs. Located in Cincinnati, Ohio, Quantum's R&D scientists possess over 30 years of experience to assure you everything you need to optimize your formulas relative to volatility, extreme temperature performance, oxidation resistance, elastomer swell control and additive solubility.

For more information about the widest selection of synthetic lubricant basestocks in the industry, contact the Chemical Specialties Group of Quantum Chemical Corporation's Emery Division.

Research over the full range of PAO and ester-based synthetic lubricants is headquartered in the Emery Technical Center in Cincinnati, Ohio.

Material Safety Data Sheets for these products are provided with samples or are available on request. Users of these products are urged to study and use this information.

Emery® PAO fluids are available in bulk or 55 gallon steel non-returnable drums. For additional information on pricing, availability or technical assistance, please contact:

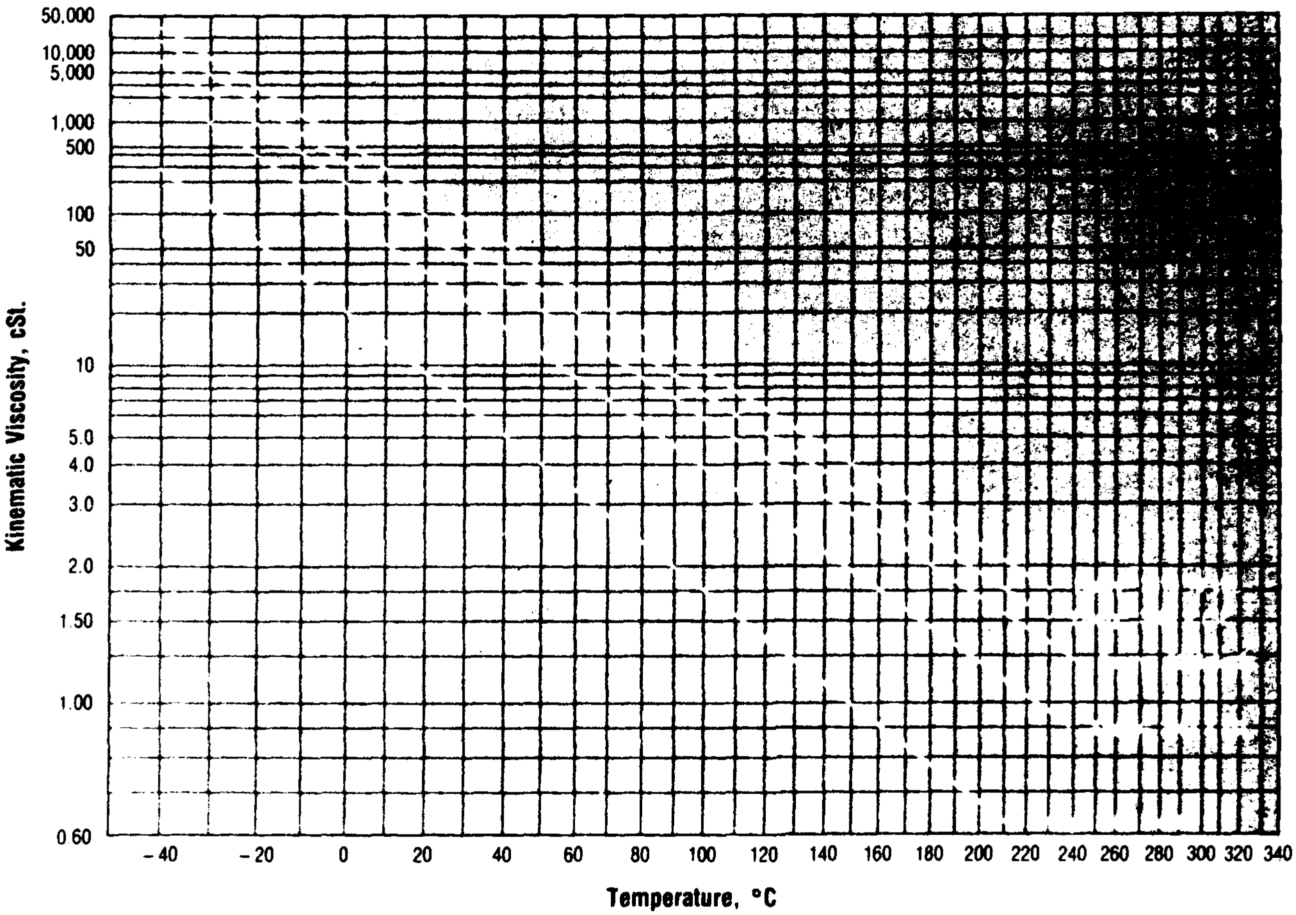
United States
Quantum Chemical Corporation
Emery Division
Chemical Specialties Group
11501 Northlake Drive
Cincinnati, Ohio 45249
Phone: (513) 530-7300
Telefax: (513) 530-7443

Canada
Quantum Chemical Ltd.
365 Evans Avenue, Suite 601
Toronto Ontario M8Z 1K2
Phone: (416) 259-3751

Typical Properties of Emery® PAO Basestocks

Properties and Test Methods	Emery® 3002 2cSt.PAO	Emery® 3004 4cSt.PAO	Emery® 3006 6cSt.PAO	Emery® 3008 8cSt.PAO	Emery® 3010 10cSt.PAO
Viscosity, cSt. (ASTM D-445)					
149°C	0.98	1.89	2.59	3.32	4.00
100°C	1.72	3.86	5.85	7.90	10.0
40°C	5.12	16.9	30.9	48.5	68.2
0°C	19.6	94.5	214.0	438.5	657.0
−40°C	242	2,520	8,190	21,040	43,800
Brookfield viscosity, 25°C, cP	5.5	34.5	62.5	107.5	130.5
Viscosity index (ASTM D-2270)	122	123	135	132	130
Bromine number (ASTM D-1159 Modified)	0.3	0.3	0.3	0.3	0.3
Moisture, ppm (ASTM D-1744)	25	25	25	25	25
Pour point, °C (ASTM D-97)	−65	−69	−64	−59	−55
Flash point, °C (ASTM D-92)	164	225	243	264	280
Fire point, °C (ASTM D-92)	178	250	266	288	298
Color, % trans. @ 440 nm (Quantum 106.01)	99	99	99	99	96
Total acid number (ASTM D-974)	<0.01	<0.01	<0.01	<0.01	<0.01
Autoignition temperature, °C (ASTM D-2155)	324	343	371	377	377
Specific gravity, 15.6/15.6°C (ASTM D-1298)	0.797	0.819	0.827	0.832	0.836
Density, lbs./gal., 60°F	6.64	6.82	6.89	6.93	6.96

Viscosity/Temperature Relationship of Emery® Polyalphaolefins

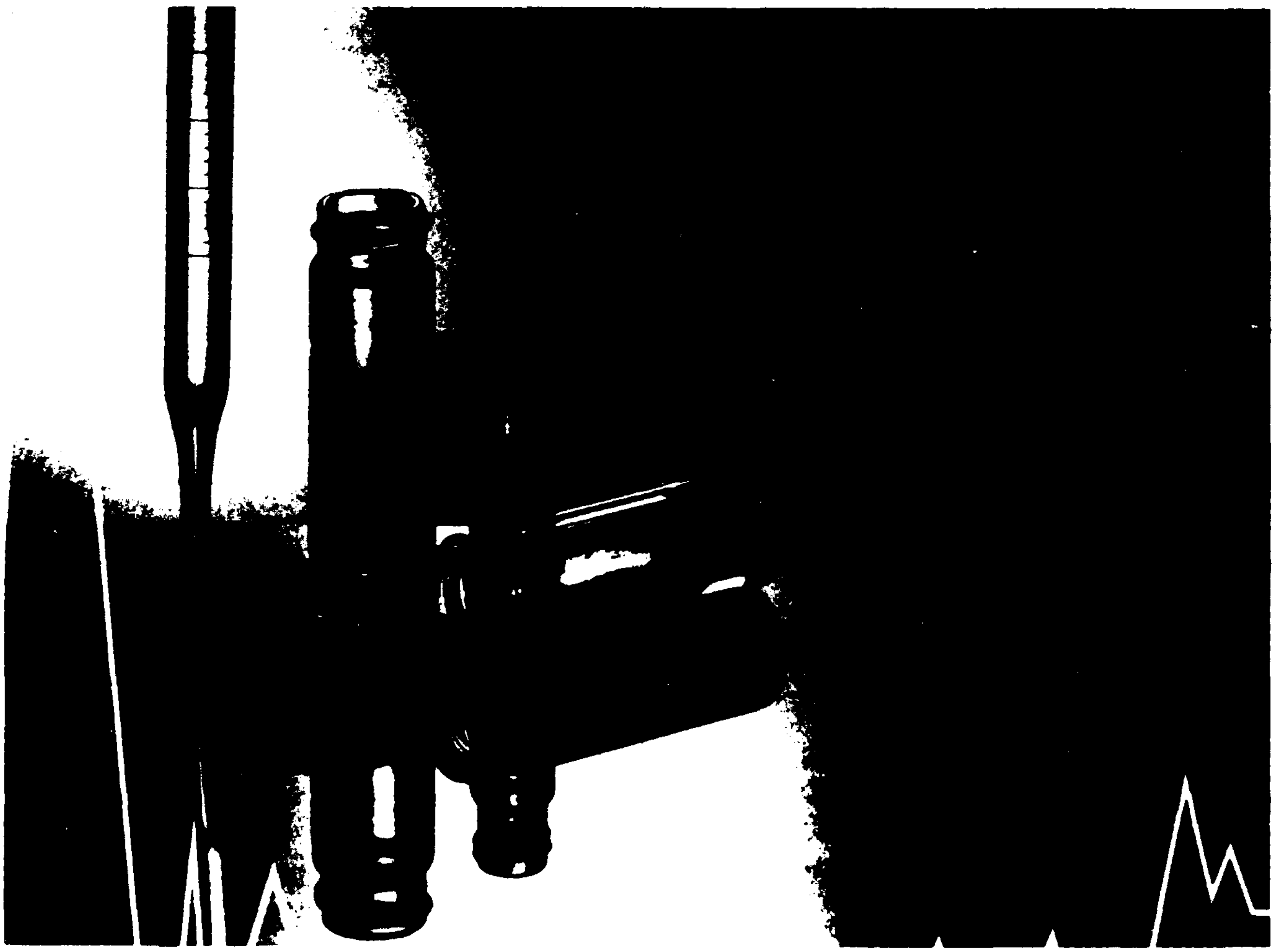


Emersol® 871 and 875 Isostearic Acids

Technical Bulletin 116I

EXP1 PULSE SEQUENCE STD1H
SOLVENT CDCL3
FILE H

OBSERVE PROTON
FREQUENCY 200.057 MHZ
SPECTRAL WIDTH 4000 HZ
ACQ. TIME 3.752 SEC



Quantum

Quantum

Emersol® 871 and 875 Isostearic Acids

Technical Bulletin 116I

Emersol® 871 and Emersol® 875 Isostearic Acids (CAS 30399-84-9) are liquid isomers of stearic acid that combine the saturation of stearic acid with the liquid nature and solubility characteristics of oleic acid. This combination results in derivatives resembling those of oleic acid and possessing stearic acid's stability against oxidation.

Chemically, Emersol 871 and Emersol 875 Isostearic Acids are C_{18} saturated fatty acids of the formula $C_{17}H_{35}$ COOH. Evidence to date indicates that they are complex mixtures of isomers, primarily of the methyl-branched series, that are mutually soluble and virtually inseparable. As a result, titer or freezing points are much lower than titers ordinarily encountered in saturated fatty acids of this molecular weight.

For applications requiring extremely light color and stability, the excellent initial color and proven stability of Emersol 875 are readily suited. Emersol 871 offers similar properties but does not exhibit an initial color as light as Emersol 875. With this exception, its performance is comparable to Emersol 875.

Particularly promising derivatives of Emersol 871 and Emersol 875 Isostearic Acids include esters, alkali metal and alkanolamine soaps, amine condensates and other surface active agents, sulfated alcohols, amides, quaternary compounds and polymerizable derivatives.

Industrial products in which both Emersol 871 and Emersol 875 have been investigated include cosmetics, detergents, emulsifiers, sanitary chemicals, lubricants, greases, textile chemicals, carbon paper, paper coatings, rubber and plastics.

Specifications and Characteristics of Emersol® Isostearic Acids — **Table 1**

Specifications	**Emersol® 871**	**Emersol® 875**
Titer, °C, max.	10.0	10.0
Iodine value, max.	12.0	3.0
Acid value	175 min.	187-197
Color, % transmission, 440/550 nm, min.	30/85	85/98
Typical Characteristics		
Molecular weight (approx.)	284	284
Unsaponifiables, %	5.6	—
Refractive index, 25°C	1.4640	1.4547
Viscosity, cP, 25°C	48	43.1
Specific gravity at 70°F	0.897	0.888
at 100°F	0.888	0.879
at 180°F	0.862	0.853
Density, lbs./gal., at 70°F	7.49	7.4
at 100°F	7.39	7.3
at 180°F	7.18	7.1

Composition of Emersol 871 and Emersol 875 Isostearic Acids — **Table 2**

	Emersol 871		**Emersol 875**	
	"Normal" Acids	**"Iso" Acids**	**"Normal" Acids**	**"Iso" Acids**
C_{14}	1-3%	—	7-11%	—
C_{16}	6-8%	1-3%	4-5%	6-7%
C_{18}	8-10%	60-66%	1-2%	70-76%
$C_{18:1}$	6-12%	13-17%	1-2%	—
Unknown ca.	8-12%	—	4%	—

All data including the formulations and procedures ...ed to be correct. How... ...epted as a guarantee of ...ng tests should be run ...orporation in your own plant or laboratory. No statement should be construed as a recommendation for any use which would violate any patent rights. Sales of all products are pursuant to terms and conditions included in Quantum sales documents. Nothing contained herein shall constitute a guarantee or warranty with respect to the products described or their use.

APPENDIX B

A 445 March 1988 Printed in U.S.A.

Oxidation Stability

The exceptional oxidation stabilities of Emersol 871 and Emersol 875 Isostearic Acid derivatives, compared with those of commercial stearic and oleic acids, are shown in Table 3.

Pour Points

The low titer of isostearic acid compared with that of commercial grades of stearic acid is also shown by its derivatives. As examples, the pour points of derivative esters are listed in Table 4.

Solubility

Solubility characteristics of isostearic soaps are very similar to those of oleic acids. Solubility characteristics of lead and zinc salts of Emersol 871 and Emersol 875 are shown in Tables 5 and 7. Solubility characteristics of various derivatives in organic solvents are shown in Tables 6 and 8.

Toxicity

Acute Oral LD_{50} values in rats were found to be greater than 32.0 cc/kg. Acute skin irritation studies on rabbits resulted in primary irritation indices of 0.50 and 0.63 for Emersol 871 and Emersol 875, respectively, on the Draize scale of 0 to 8.0. Repeated application of Emersol 875 to humans for three weeks followed by challenge applications revealed no evidence of irritation or sensitization.

Based on these results, the acute oral toxicity, irritation and sensitization potentials of these materials are not expected to be high.

Availability

Emersol 871 and Emersol 875 Isostearic Acids are available in 55-gallon lined, nonreturnable steel drums and 10,000 and 20,000 gallon tankcars. For prices, delivery or any other information, contact Oleochemicals Group of Quantum Chemical Corporation's Emery Division, Cincinnati, Ohio.

Oxidation Stability — **Table 3**

Product	Time Required to Absorb 10 ml. Oxygen at 60°C
Emersol 875 Isostearic Acid	100 days
Emersol 871 Isostearic Acid	100 days
Commercial oleic acid (93 I.V.)	1-7 days
Double pressed stearic acid (5.0 I.V.)	25 days
Glyceryl tri-isostearate	110 hours
Glyceryl tri-oleate	5 hours

Pour Points of Derivative Esters — **Table 4**

Ester	E-871 Isostearate	Stearate	Oleate	E-875 Isostearate
Methyl	−26°F	+ 80°C	− 4°F	
Ethyl	−22°F			
n-Propyl	−25°F			−72°F
n-Butyl	−25°F	+ 65°F	−14°F	
Isotridecyl	−42°F	+ 30°F	−46°F	
Glyceryl (mono)	+ 6°F	+133°F	+34°F	−22°F
Glyceryl (tri)	−12°F	+127°F	− 4°F	
Ethylene glycol (di)	− 5°F			
Propylene glycol (mono)	+ 6°F			

Test method: A 25 g sample of test product is held at 60°C in a sealed 250 ml flask (fitted with a mercury-filled manometer) under an air blanket. The test is arbitrarily concluded when 10 ml of oxygen (STP) are absorbed by the sample.

Solubilities of Pb and Zn Salts of Emersol 871 Isostearic Acid — **Table 5**

Solvent	Zinc Isostearate	Zinc Oleate	Zinc Stearate	Lead Isostearate	Lead Oleate	Lead Stearate
Acetone	Sl S	Sl S[1]	I	I[2]		I
Carbon tetrachloride	S		S	S		S
Chloroform	S		Sl.S	S		
Ethyl acetate	S		I	S		I
n-Heptane	S	S		S		
Isopropanol	I			I[2]		
Mineral oil	S	S	S	S		S
Glycerine	I			I		
Propylene glycol	I	I	I	I		
Ethyl ether	S	S	I	S	S	I
Toluene	S		S	S		S
Water	I	I	I	I	I	I

[1]Dissolved upon heating, but partially precipitated upon cooling
[2]Partially dissolved upon heating, but precipitated upon cooling
S = Soluble
Sl S = Slightly Soluble
I = Insoluble

APPENDIX B

2

Solubilities of Emersol 871 Isostearic Acid Derivatives **Table 6**

Solvent	Ethyl Isostearate	n-Propyl Isostearate	Glyceryl Mono-Isostearate	Polyethylene Glycol 600 Mono-Isostearate	Ethylene Glycol Di-Isostearate	Propylene Glycol Mono-Isostearate	n-Isostearic Diethanolamine
Acetone	S	S	S	S	S	S	S[1]
Carbon tetrachloride	S	S	S	S	S	S	S
Chloroform	S	S	S	S	S	S	S
Ethyl acetate	S	S	S	S	S	S	S
n-Heptane	S	S	S	Sl.S	S	S	S
Isopropanol	S	S	S	S	S	S	S
Mineral oil	S	S	S	S	S	S	S
Glycerine	I	I	S	S	Sl.S	S	S
Propylene glycol	Sl.S	Sl.S	S	S	Sl.S	S	S
Ethyl ether	S	S	S	S	S	S	S
Toluene	S	S	S	S	S	S	S
Water	I	I	I[2]	S	I	I	I

[1]A small amount of white suspended material was present
[2]Formed an emulsion
S = Soluble
Sl.S = Slightly Soluble
I = Insoluble

Solubilities of Pb and Zn Salts of Emersol 875 Isostearic Acid **Table 7**

Solvent	Zinc Isostearate	Zinc Oleate	Zinc Stearate	Lead Isostearate	Lead Oleate	Lead Stearate
Acetone	Sl.S	Sl.S[1]	I	I[2]		I
Carbon tetrachloride	S		S	S		S
Chloroform	S		Sl.S	S		
Ethyl acetate	S		I	S		I
n-Heptane	S	S		S		
Isopropanol	I			I[2]		
Mineral oil	S	S	S	S		S
Glycerine	I			I		
Propylene glycol	I	I	I	I		
Ethyl ether	S	S	I	S	S	I
Toluene	S		S	S		S
Water	I	I	I	I	I	I

[1]Dissolved upon heating but partially precipitated upon cooling
[2]Partially dissolved upon heating but precipitated upon cooling
S = Soluble
Sl.S = Slightly Soluble
I = Insoluble

Solubilities of Emersol 875 Isostearic Acid Derivatives **Table 8**

Solvent	Ethyl Isostearate	n-Propyl Isostearate	Glyceryl Mono-Isostearate	Polyethylene Glycol 600 Mono-Isostearate	Ethylene Glycol Di-Isostearate	Propylene Glycol Mono-Isostearate	n-Isostearic Diethanolamine
Acetone	S	S	S	S	S	S	S[1]
Carbon tetrachloride	S	S	S	S	S	S	S
Chloroform	S	S	S	S	S	S	S
Ethyl acetate	S	S	S	S	S	S	S
n-Heptane	S	S	S	Sl.S	S	S	S
Isopropanol	S	S	S	S	S	S	S
Mineral oil	S	S	S	S	S	S	S
Glycerine	I	I	S	S	Sl.S	S	S
Propylene glycol	Sl.S	Sl.S	S	S	Sl.S	S	S
Ethyl ether	S	S	S	S	S	S	S
Toluene	S	S	S	S	S	S	S
Water	I	I	I[2]	S	I	I	I

[1]A small amount of white suspended material was present
[2]Formed an emulsion

S = Soluble
Sl S = Slightly Soluble
I = Insoluble

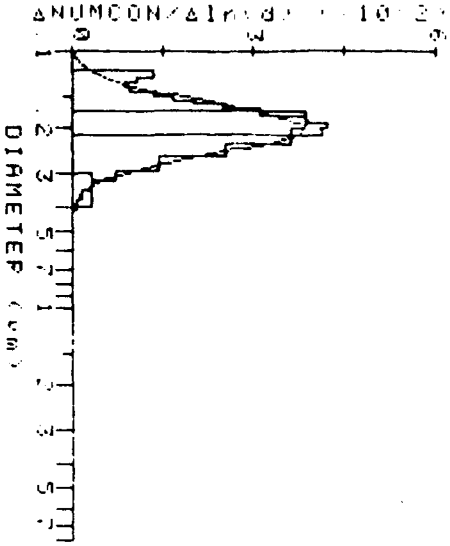
Blank

APPENDIX C

Comparison of Performance of DOP, "Emery 3004" PAO, and "Emersol 875" Isostearic Acid in New TDA-100 Machines

Testing was carried out using three new production-line machines at the manufacturer's (ATI's)[8] plant during four visits on February 9, March 9, 12, and April 3, 1990. One material was placed in each machine and allowed to age at temperature, typically 175 °C, for several days. On the following pages, typical data are shown. The geometric mean diameter (GMD) in um and the geometric standard deviation (GSD) are underlined on each chart as printed out by the "LAS-X" laser aerosol spectrometer.[7]

DOP



DATE 90/3/9 TIME 152420 PSLF
MAX CNTS/SEC= 1116 SEC= 20
R:0-3 TRUN 0 BINS 5.00 ML/SEC
DILUTION RATIO = 1.000E+000
TEMPERATURE (C)= 2.200E+001
ATM PRESSURE (mm Hg)= 7.600E+002
REL HUMIDITY (%)= 5.000E+001
A PARAMETER = 0.000E+000
B PARAMETER = 0.000E+000
C PARAMETER = 0.000E+000
NUM CONC (NUMB/cm3)= 2.242E+002
GEOM MEAN DIAM (um)= 2.004E-001
GEOM STANDARD DEV = 1.262E+000
MASS CONC (mg/m3)= 1.210E-003
UNDIL MASSCON(mg/m3)= 1.210E-003
MAX CNTS/SEC = 1.116E+003
PEAK DIAMETER (um) = 1.950E-001
FIT NUM CONC (#/cm3)= 0.000E+000
FIT GEOM MN DIA (um)= 1.000E-008
FIT GEOM STAND DEV = 1.000E+002
FIT UNDIL M0 (mg/m3)= 0.000E+000

PROBE RANGE=3 TOT CNTS= 22314

BIN	DIA	COUNT	DISTN VALUE
0	.120	659	1.35E+002
1	.126	493	1.07E+002
2	.132	385	8.66E+001
3	.138	463	9.47E+001
4	.144	547	1.34E+002
5	.150	657	1.68E+002
6	.156	759	2.01E+002
7	.162	908	2.50E+002
8	.168	1098	3.13E+002
9	.174	1060	3.13E+002
10	.180	1269	3.87E+002
11	.186	1235	3.89E+002
12	.192	1301	4.27E+002
13	.198	1224	4.10E+002
14	.204	1197	4.13E+002
	.210 (	9113=OVERCOUNT)	

[illegible]	[illegible]	[illegible]	[illegible]
0	.170	6267	3.85E+002
1	.200	5054	3.62E+002
2	.230	3103	2.53E+002
3	.260	1579	1.45E+002
4	.290	732	7.44E+001
5	.320	304	3.39E+001
6	.350	138	1.68E+001
7	.380	61	9.03E+000
8	.410	14	1.98E+000
9	.440	1	1.52E-001
10	.470	1	1.62E-001
11	.500	0	0.00E+000
12	.530	0	0.00E+000
13	.560	0	0.00E+000
14	.590	0	0.00E+000
	.620 (	1=OVERCOUNT)	

PROBE RANGE=1 TOT CNTS= 1072

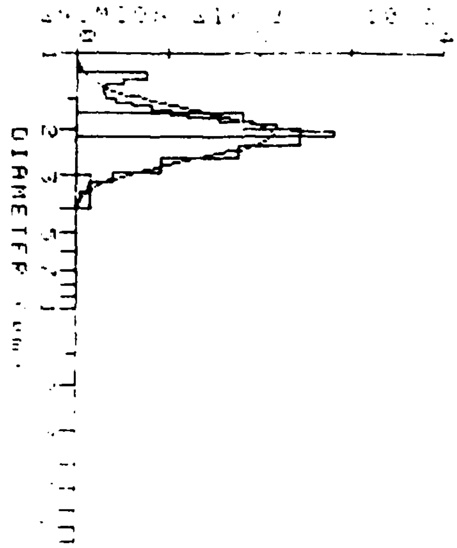
BIN	DIA	COUNT	DISTN VALUE
0	.300	1008	3.50E+001
1	.400	63	2.82E+000
2	.500	0	0.00E+000
3	.600	0	0.00E+000
4	.700	1	7.49E-002
5	.800	0	0.00E+000
6	.900	0	0.00E+000
7	1.000	0	0.00E+000
8	1.100	0	0.00E+000
9	1.200	0	0.00E+000
10	1.300	0	0.00E+000
11	1.400	0	0.00E+000
12	1.500	0	0.00E+000
13	1.600	0	0.00E+000
14	1.700	0	0.00E+000
	1.800 (	0=OVERCOUNT)	

PROBE RANGE=0 TOT CNTS= 0

BIN	DIA	COUNT	DISTN VALUE
0	1.500	0	0.00E+000
1	1.900	0	0.00E+000
2	2.300	0	0.00E+000
3	2.700	0	0.00E+000
4	3.100	0	0.00E+000
5	3.500	0	0.00E+000
6	3.900	0	0.00E+000
7	4.300	0	0.00E+000
8	4.700	0	0.00E+000
9	5.100	0	0.00E+000
10	5.500	0	0.00E+000
11	5.900	0	0.00E+000
12	6.300	0	0.00E+000
13	6.700	0	0.00E+000
14	7.100	0	0.00E+000
	7.500 (	0=OVERCOUNT)	

Table C.1 Typical Performance of DOP in a New TDA-100 Machine:
GMD = 0.2004 um, GSD = 1.262.

EMERY 3004



DATE 90/3/30 TIME 132600 OTH-
MAX CNTS SEC= 598 SEC= 20
P 0-3 TRUN 0 BINS 5 00 ML SEC
DILUTION RATIO = [illegible]E+000
TEMPERATURE (C)= [illegible]00E+001
ATM PRESSURE (mm Hg)= 7 [illegible]00E+002
REL HUMIDITY (%)= 5 000E+001
A PARAMETER = 0 000E+000
B PARAMETER = 0.000E+000
C PARAMETER = 0 000[illegible]+000
NUM CONC (NUMB/cm3)= 1 [illegible]+002
GEOM MEAN DIAM (um)= [illegible]
GEOM STANDARD DEV = [illegible]
MASS CONC (mg/m3)= [illegible]
UNDIL MASSCON(mg/m3)= [illegible]
MAX CNTS/SEC = [illegible]
PEAK DIAMETER (um) = [illegible]
FIT NUM CONC (#/cm3)= [illegible]
FIT GEOM MN DIA (um)= 1 000E-00[illegible]
FIT GEOM STAND DEV = 1 000E+00[illegible]
FIT UNDIL M0 (mg/m3)= [illegible]000

PROBE RANGE=3 TOT CNTS= [illegible]

BIN	DIA	COUNT	DISTN VALUE
0	.120	382	7.83E+001
1	.126	233	5.01E+001
2	.132	145	3.26E+001
3	.138	1[illegible]1	7.38E+001
4	.144	1[illegible]8	7.[illegible]E+001
5	.150	1[illegible]	[illegible]
6	.156	2[illegible]	[illegible]
7	.162	303	[illegible]
8	.168	3[illegible]4	1.04E+002
9	.1[illegible]	4[illegible]	1.[illegible]E+002
10	.180	5[illegible]	1.[illegible]E+002
11	.186	611	1.[illegible]E+002
12	.192	677	2.19E+002
13	.198	6[illegible]	2.74E+002
14	.204	817	2.[illegible]E+002
	.210 (	6160=OVERCOUNT)	

BIN	DIA	COUNT	DISTN VALUE
0	.170	2940	1.81E+002
1	.200	3414	2.44E+002
2	.230	2171	1.77E+002
3	.260	1013	9.28E+001
4	.290	404	4.10E+001
5	.320	135	1.51E+001
6	.350	43	5.23E+000
7	.380	9	1.18E+000
8	.410	1	1.42E-001
9	.440	0	0.00E+000
10	.470	0	0.00E+000
11	.500	0	0.00E+000
12	.530	0	0.00E+000
13	.560	0	0.00E+000
14	.590	0	0.00E+000
	.620 (	1=OVERCOUNT)	

PROBE RANGE=1 TOT CNTS= 521

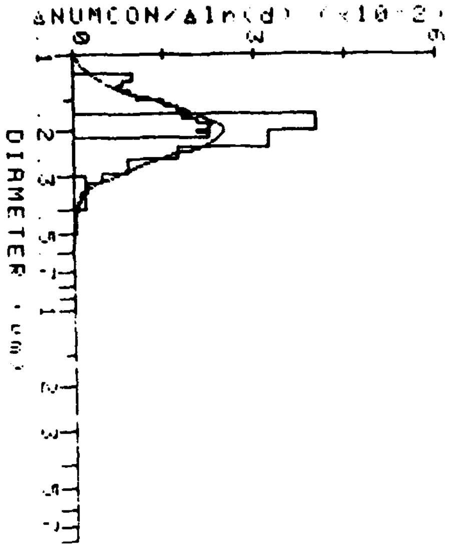
BIN	DIA	COUNT	DISTN VALUE
0	.300	516	1.79E+001
1	.400	4	1.79E-001
2	.500	0	0.00E+000
3	.600	1	6.49E-002
4	.700	0	0.00E+000
5	.800	0	0.00E+000
6	.900	0	0.00E+000
7	1.000	0	0.00E+000
8	1.100	0	0.00E+000
9	1.200	0	0.00E+000
10	1.300	0	0.00E+000
11	1.400	0	0.00E+000
12	1.500	0	0.00E+000
13	1.600	0	0.00E+000
14	1.700	0	0.00E+000
	1.800 (	0=OVERCOUNT)	

PROBE RANGE=0 TOT CNTS= 0

BIN	DIA	COUNT	DISTN VALUE
0	1.500	0	0.00E+000
1	1.900	0	0.00E+000
2	2.300	0	0.00E+000
3	2.700	0	0.00E+000
4	3.100	0	0.00E+000
5	3.500	0	0.00E+000
6	3.900	0	0.00E+000
7	4.300	0	0.00E+000
8	4.700	0	0.00E+000
9	5.100	0	0.00E+000
10	5.500	0	0.00E+000
11	5.900	0	0.00E+000
12	6.300	0	0.00E+000
13	6.700	0	0.00E+000
14	7.100	0	0.00E+000
	7.500 (	0=OVERCOUNT)	

Table C.2 Typical Performance of "Emery 3004" Polyalphaolefin (PAO) in a New TDA-100 Machine; GMD = 0.2083 um, GSD = 1.245.

Emersol 875



DATE 90/3/9 TIME 110320 PSLF
MAX CNTS/SEC= 758 SEC= 20
R 0-3 TRUN 0 BINS 5.00 ML/SEC

DILUTION RATIO	=	1.000E+000
TEMPERATURE	(C)=	2.200E+001
ATM PRESSURE	(mm Hg)=	7.600E+002
REL HUMIDITY	(%)=	5.000E+001
A PARAMETER	=	0.000E+000
B PARAMETER	=	0.000E+000
C PARAMETER	=	0.000E+000
NUM CONC	(NUMB/cm3)=	1.560E+002
GEOM MEAN DIAM	(um)=	2.002E 001
GEOM STANDARD DEV	=	1.284E+000
MASS CONC	(mg/m3)=	9.822E-004
UNDIL MASSCON	(mg/m3)=	9.822E-004
MAX CNTS/SEC	=	7.583E+002
PEAK DIAMETER	(um) =	2.198E-001
FIT NUM CONC	(#/cm3)=	0.000E+000
FIT GEOM MN DIA	(um)=	1.000E-009
FIT GEOM STAND DEV	=	1.000E+002
FIT UNDIL M0	(mg/m3)=	0.000E+000

PROBE RANGE=3 TOT CNTS= 13115

BIN	DIA	COUNT	DISTN VALUE
0	.120	466	9.96E+001
1	.126	398	8.56E+001
2	.132	340	7.65E+001
3	.138	413	9.70E+001
4	.144	447	1.10E+002
5	.150	583	1.50E+002
6	.156	582	1.54E+002
7	.162	635	1.75E+002
8	.168	677	1.93E+002
9	.174	617	1.82E+002
10	.180	677	2.06E+002
11	.186	724	2.28E+002
12	.192	696	2.26E+002
13	.198	617	2.07E+002
14	.204	653	2.25E+002
	.210 (	4564=OVERCOUNT)	

PROBE RANGE=2 TOT CNTS= 15156

BIN	DIA	COUNT	DISTN VALUE
0	.170	6554	4.03E+002
1	.200	4501	3.22E+002
2	.230	2132	1.74E+002
3	.260	1015	9.30E+001
4	.290	463	4.70E+001
5	.320	223	2.49E+001
6	.350	137	1.54E+001
7	.380	90	1.05E+001
8	.410	47	5.24E+000
9	.440	19	2.88E+000
10	.470	5	8.08E-001
11	.500	2	3.43E-001
12	.530	2	3.63E-001
13	.560	1	1.92E-001
14	.590	0	0.00E+000
	.620 (	4=OVERCOUNT)	

PROBE RANGE=1 TOT CNTS= 773

BIN	DIA	COUNT	DISTN VALUE
0	.300	654	2.27E+001
1	.400	108	4.84E+000
2	.500	5	2.74E-001
3	.600	1	6.49E-002
4	.700	2	1.50E-001
5	.800	0	0.00E+000
6	.900	2	1.90E-001
7	1.000	1	1.05E-001
8	1.100	0	0.00E+000
9	1.200	0	0.00E+000
10	1.300	0	0.00E+000
11	1.400	0	0.00E+000
12	1.500	0	0.00E+000
13	1.600	0	0.00E+000
14	1.700	0	0.00E+000
	1.800 (	0=OVERCOUNT)	

PROBE RANGE=0 TOT CNTS= 2

BIN	DIA	COUNT	DISTN VALUE
0	1.500	1	4.23E-002
1	1.900	0	0.00E+000
2	2.300	1	6.24E-002
3	2.700	0	0.00E+000
4	3.100	0	0.00E+000
5	3.500	0	0.00E+000
6	3.900	0	0.00E+000
7	4.300	0	0.00E+000
8	4.700	0	0.00E+000
9	5.100	0	0.00E+000
10	5.500	0	0.00E+000
11	5.900	0	0.00E+000
12	6.300	0	0.00E+000
13	6.700	0	0.00E+000
14	7.100	0	0.00E+000
	7.500 (	0=OVERCOUNT)	

Table C.3 Typical Performance of Emersol 875 Isostearic Acid in a New TDA-100 Machine: GMD = 0.2002 um, GSD = 1.284.

APPENDIX D

Approval for Use of "Emery 3004" to Replace DOP in Testing at Aberdeen Proving Ground (APG)

SMCCR-HV (SMCCR-RS/23 Mar 90) (40-5e) 1st End
SUBJECT: Safe Replacement Material for Dioctyl Phthalate (DOP)

SMCCR-HV APR 11 1990

FOR SMCCR-RS (Mr. Carlon)

1. References.

a. Guiney, P. D., "Acute Toxicity Assessment of Polyalphaolefin (PAO) Synthetic Fluids", presented at the Symposium on Synthetic and Petroleum Based Lubricants, American Chemical Society, April 1982.

b. Material Safety Data Sheet (MSDS) for Emery 3004, Synthetic Hydrocarbon Fluid, March 1989.

2. We have reviewed references a and b and concur with the use of Emery 3004 as a substitute for DOP in filter penetrometers used by CRDEC/AMCCOM elements in Edgewood. Engineering and work practice controls must maintain exposures below the PEL of 5 mg/cubic meter recommended for oil mist in 29 CFR 1910.1000.

3. Further, we will staff the issue with higher headquarters for Army-wide use as you requested.

4. Point of contact is Mr. Paul K. Buckmaster, M.S., CIH, Senior Industrial Hygienist, SMCCR-HV, ext 3043.

Thomas F Nalepa

Encl
nc

THOMAS F. NALEPA
COL, MS
Chief, Hlth & Vet Svcs Ofc

CF:
SMCCR-SF/Mrs. Trask
SMCCR-RS/Dr. Salem

HSHB-ZH (40-5e) 9 April 1990

MEMORANDUM FOR HSHB-MO-T (Mr. Leach)

SUBJECT: Safe Replacement Material for Dioctyl Phthalate (DOP)

1. References.

a. Memorandum, SMCCR-RS, 20 Mar 90, SAB (encl 1).

b. Guiney, P. D., "Acute Toxicity Assessment of Polyalphaolefin (PAO) Synthetic Fluids", presented at the Symposium on Synthetic and Petroleum Based Lubricants, American Chemical Society, April 1982 (encl 2).

c. Material Safety Data Sheet (MSDS) for Emery 3004, Synthetic Hydrocarbon Fluid, March 1989 (encl 3).

2. As part of an ongoing program to identify a technically feasible substitute for DOP in penetrometer filter tests, CRDEC has recommended the use of a polyalphaolefin (PAO) manufactured by Henkel Chemical Corporation. This compound (Emery 3004) is a synthetic hydrocarbon produced by polymerizing 1-decene, then hydrogenating the resulting compound to form a saturated straight chain hydrocarbon (20 carbon).

3. Acute toxicity studies on PAOs (encl 2) indicate this class of compounds is relatively non-toxic. Data is comparable with that of mineral oils produced from paraffinic petroleum base stock, however, the PAOs do not contain toxic impurities such as polynuclear aromatic compounds, volatile aromatics and napthenic compounds. A MSDS for Emery 3004 is enclosed (encl 3).

4. Request your office review the enclosed data and provide comments on the use of Emery 3004 as a substitute for DOP in penetrometer filter test operations. We will be staffing this issue with higher headquarters to get DA approval for the use of this compound and would like to resolve any major issues now. Please provide comments by 27 April 90.

5. Point of contact for this office is Mr. Paul K. Buckmaster, M.S., CIH, Senior Industrial Hygienist, HSHB-ZH, ext 3043. Questions related to the technical feasibility should be addressed to Mr. Hugh Carlon, P.E., ext 4106.

Thomas F. Nalepa

THOMAS F. NALEPA
COL, MS
Chief, Hlth & Vet Svcs Ofc

3 Encls
as

CF:
SMCCR-RS/Mr. Carlon

DEPARTMENT OF THE ARMY
U.S. ARMY CHEMICAL RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MARYLAND 21010-5423

REPLY TO
ATTENTION OF

SMCCR-RS (70-1g) 23 MAR 1990

MEMORANDUM FOR HEALTH AND VETERINARY SERVICES OFFICE (HVSO) (Mr. P. Buckmaster)

SUBJECT: SAFE REPLACEMENT MATERIAL FOR DIOCTYL PHTHALATE (DOP)

1. Reference meeting 20 March 1990 at HVSO between Paul K. Buckmaster, and Hugh R. Carlon, of Research Directorate, subject as above.

2. The enclosure discusses a safe replacement material for the suspected carcinogen, DOP, in gas mask and filter-testing penetrometer machines. Copies of all reference documents cited in the enclosure were provided to Mr. Buckmaster at the above meeting.

3. Request that HVSO review enclosure and reference documents, and issue written approval for use of the safe material to replace DOP in "hot smoke" testing machines presently being operated at Aberdeen Proving Ground.

4. Request further that HVSO recommend approval for use of the safe material command-wide by endorsement to Army Material Command (AMC), and Army-wide by recommending endorsement of AMC to the Army Surgeon General.

HARRY SALEM
Acting Director, Research

Enclosure
as stated

Memorandum

H.R. Carlon
20 March 90

SAFE REPLACEMENT MATERIAL FOR DIOCTYL PHTHALATE (DOP)

1. Documents referenced in this memorandum:

A. Carlon, H.R., Guelta, M.A., and Gerber, B.V., "A Study of Candidate Replacement Materials for DOP in Filter-Testing Penetrometer Machines," CRDEC-TR-053, March 1989, U.S. Army CRDEC, Aberdeen Proving Ground, MD 21010-5423.

B. Eastman Kodak Co., Kingsport, TN 37662, Material Safety Data Sheet (MSDS) for "KODAFLEX" DOP Plasticizer, date of preparation 29 December 1988.

C. Henkel Chemical Corp., Emery Div., 4900 Este Avenue, Cincinnati, OH 45232, Material Safety Data Sheet (MSDS) for "Emery 3004" Synthetic Hydrocarbon 4 CST Fluid (Polyalphaolefin), date of preparation 31 March 1989.

D. Guiney, P.D., "Acute Toxicity Assessment of Polyalphaolefin (PAO) Synthetic Fluids," Proc. Symposium on Synthetic and Petroleum Based Lubricants, Div.,of Petroleum Chemistry, American Chemical Socy., Las Vegas, NV, 28 March- 2 April 1982, pp. 381-389.

E. Carlon, H.R., et al, "Infrared Extinction Spectra of Some Common Liquid Aerosols," Applied Optics 16, 1598-1605 (1977).

2. This memorandum discusses a safe replacement material for the suspected carcinogen, dioctyl phthalate (DOP), in gas mask and filter-testing penetrometer machines. The new, safe material is intended primarily to replace DOP directly in "hot smoke", "monodispersed" filter-testing machines, although it will find use in other testing applications as well. The new material can be used to replace DOP directly in existing and new hot smoke machines, without machine modification. It meets or exceeds all Army test specifications, and frequently outperforms DOP. It is inexpensive and readily-available, similar in both respects to DOP. The new material is a polyalphaolefin (PAO) or synthetic hydrocarbon, made by a special process to have nearly 100% purity. It is similar to a mineral oil of very high purity, but because it is manufactured rather than distilled from petroleum, it consists almost entirely of a hydrocarbon of a single carbon chain length rather than a distribution of chain lengths, as is found in petroleum-derived mineral oils. It is this high purity of a single chain length that enables it to vaporize and recondense in a hot smoke machine to produce test aerosol droplets very nearly of a single diameter, i.e., a nearly "monodispersed" aerosol or smoke; this cannot be achieved with petroleum-based mineral oils, however otherwise pure.

3. This memorandum considers exclusively a PAO made by Emery (Ref. C, above), called "Emery 3004." It has a 20-carbon molecular chain, and this results in physical properties including a viscosity of 4 centistokes (CST). Other materials in the same family, which are useful in other test machines,

include the 10-carbon-chain Emery 3002 (2 CST), and the 30-carbon-chain Emery 3006 (6 CST). But the Emery 3004 performs best in the standard U.S. Army "Q-127" hot smoke test machines used for 100% mask filter canister quality control testing; these machines are manufactured by Air Techniques, Inc. (ATI), in Baltimore, MD.

4. Emery 3004 was identified as a safe candidate material to replace DOP in an extensive program carried out by Research Directorate, CRDEC, with funding provided by Product Assurance Directorate (PAD), APG, MD (Ref. A, above). As described in Ref. A, dozens of candidate materials were selected on the basis of very low toxicity, no indications of carcinogenicity, and physical properties such that they would vaporize and recondense in penetrometer machines including the Q-127 so as to produce nearly monodispersed test smokes meeting U.S. Army and thus PAD standards like those met using DOP. These specifications include a geometric mean diameter (GMD) of 0.3 um (ideally adjustable to smaller diameters), a geometric standard deviation (GSD, a measure of size distribution width) less than or equal to 1.30, and a smoke aerosol mass concentration at the filter test chuck of 100 mg/m^3.

5. DOP had been restricted for use in these test procedures by the U.S. Army Surgeon General (who similarly restricted dioctyl sebacate (DOS)) because of its indicated carcinogenicity (potential to cause cancer). The MSDS for the DOP used as the industry standard (Ref. B, above) leaves little doubt of this. Statements include: "WARNING! POSSIBLE CANCER HAZARD - MAY CAUSE CANCER BASED ON ANIMAL DATA," and "it is generally believed that DOP produces liver tumors in rodents...." Although other statements on the DOP MSDS dispute its carcinogenicity at typical exposures, and industrial users complain because DOP is the long-established standard in their machines and test procedures, one can conclude that the Surgeon General's concerns are prudent.

6. By comparison, MSDS for the chemical family including Emery 3004 (Ref. C, above) carry no warnings of potential carcinogenicity. When these materials were originally selected for the study reported in Ref. A, their MSDS showed "unknown" under the heading "inhalation" in Sec. III, "Health Information." But during the term that the CRDEC study was determining that Emery 3004 was the best candidate to replace DOP in hot smoke machines, the manufacturer became aware of a 1982 toxicity study on PAOs (Ref. D, above). As required by law, this information was incorporated in new MSDS for the Emery 3000 series, dated 31 March 1989 (see Ref. C).

7. The Emery MSDS (Ref. C) claim that the toxicities estimated in the study of Ref. D were considered high, but that the test conditions were such that the test animals (rats) were subjected to great physical insults, sufficient that observed histopathical changes may have been a response to these insults rather than being related to a specific compound toxicity effect. The MSDS contend that PAOs may be considered non-hazardous for all practical purposes by inhalation. Indeed all oils, including the purest of mineral oils, are capable of causing "oil pneumonia" and/or death by suffocation when inhaled at very high aerosol concentrations for periods of more than many seconds to a few minutes. Since oils cannot be cleansed quickly from the lungs due to their extreme hydrophobicity, a build-up and coating of the lung surfaces is inevitable. Humans and animals subjected to such

insults respond by coughing and exiting the contaminated area. A confined test animal, on the other hand, would be subjected to great physical and psychological trauma in the presence of very high, suffocating oil aerosol concentrations, and could succumb rapidly for a variety of reasons.

8. To investigate the exact nature of conditions to which the test rats were subjected, visual and other data observations from Refs. C and D were analyzed using data from Ref. E, above, which contains optical extinction (i.e., attenuation) coefficients at wavelengths including the visible, for oil smokes and aerosols. From the extinction coefficients, the actual oil aerosol concentrations to which the rats were subjected were calculated. The test visibility conditions were such that the heads of the rats confined in test chambers could be seen under normal lighting conditions, but their hind quarters could not. This would be roughly equivalent to subjecting oneself to an oil aerosol or "fog" so thick that one could not see a hand six inches in front of his or her face. The aerosol mass concentration was estimated at 5,000 mg/m^3 (5 g/m^3), or roughly 1,000 times the PEL or TLV values normally given as safe for occupational exposure limits for oil mists (see page 2 of Ref. C, above).

9. In summary, it would appear that the test conditions under which PAOs were considered to be potentially toxic by inhalation were so unlike those reasonably expected to be found in actual experience as to focus serious doubt upon the qualifications of the investigators. Since Emery 3004 gives no indication of carcinogenicity, is safe under normal operating conditions, and can be used to replace the suspected carcinogen DOP directly in operating machines, with no mission interruption and while meeting or exceeding accepted Army filter test standards, it is strongly recommended for approval as a DOP replacement by HVSO Edgewood, AMC, and the U.S. Army Surgeon General.

Hugh R. Carlon

Hugh R. Carlon
U.S. Army Fellow
Senior Research Physicist

APPENDIX E

Approval by the U.S. Army's Office of the Surgeon General (OTSG) for Use of "Emery 3004" to Replace DOP in Testing Army-Wide

SGPS-PSP-E (SMCCR-CMH/15 Mar 91) (40-5e) 3d End MAJ Bratt/ DSN 289-0125
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

JAN 8 1992

HQDA (SGPS-PSP), 5109 Leesburg Pike, Falls Church, VA 22041-3258

FOR Commander, U.S. Army Materiel Command, ATTN: AMCSG, 5001 Eisenhower Ave, Alexandria, VA 22333-0001

1. The Office of The Surgeon General (OTSG) has reviewed the previous endorsement prepared by the Army Environmental Hygiene Agency (AEHA). This office concurs with AEHA's recommendation of approval for use of the subject compound as a replacement for dioctyl phthalate.

2. Point of contact for OTSG is MAJ Gary M. Bratt, DSN 289-0125. Specific technical questions should be directed to Mr. Glenn Leach, AEHA, DSN 584-3980/3627 or commercial (410) 671-3980/3627.

FOR THE SURGEON GENERAL:

Frederick Gullmann Col, MC

for RONALD R. BLANCK
Brigadier General, Medical Corps
Director, Professional Services

CF:
Cdr, AEHA (HSHB-MO-T)
Cdr, HSC (HSCL-P)
Cdr, MRDC (SGRD-PLC)
Cdr, CRDEC (SMCCR-CMH)

AMCSG-I (SMCCR-CMH/15 Mar 91) (40-5e) 4th End Mr. Svalina/DSN 284-9470
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

Cdr, USAMC, 5001 Eisenhower Avenue, Alexandria, VA 22333-0001 30 Jan 92

FOR Commander, U.S. Army Armament, Munitions and Chemical Command, ATTN: AMSMC-SG, Rock Island, IL 61299-6000

We have reviewed the subject toxicity clearance and are forwarding it to you as requested.

FOR THE COMMANDER:

2 Encls
nc

HOWARD A. WIENER, M.D., M.P.H.
Colonel, MC
Command Surgeon

APPENDIX E

AMSMC-SG (SMCCR-CMH/15 Mar 91) (40-5f) 5th End
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

Cdr, USA AMCCOM, Rock Island, IL 61299-6000 05 FEB 1992

FOR Commander, U.S. Army Chemical Research, Development and Engineering Center, ATTN: SMCCR-CMH, Aberdeen Proving Ground, MD 21010-5423

1. This office has reviewed the attached toxicity clearance and is forwarding it for information.

2. Point of contact is the undersigned at DSN 793-2702.

FOR THE COMMANDER:

Eric T. Evenson

2 Encls
nc

ERIC T. EVENSON, M.D., M.P.H.
LTC, MC
Command Surgeon

SMCCR-CMH (AMSMC-SG/05 Feb 92) (40-5f) 6th End
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

SMCCR-CMH 11 FEB 1992

FOR SMCCR-RSP-P (Mr. Carlon)

1. Subject document with endorsement is forwarded for your retention and appropriate action.

2. The point of contact for this office is the undersigned, SMCCR-CMH, extension 2318.

Encl

Joseph Karwatka
JOSEPH KARWATKA
MAJ, MS
Chief, Health and Veterinary
Services Office

HSHB-MO-T (SMCCR-CMH/15 Mar 91) (40-5e) 2d End Dr. Leach/jls/
DSN 584-3980
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

Commander, U.S. Army Environmental Hygiene Agency, ATTN: HSHB-MO-T, Aberdeen Proving Ground, MD 21010-5422 24 [illegible] 1991

FOR HQDA(SGPS-PSP), 5109 Leesburg Pike, Falls Church, VA 22041-3258

1. References.

a. SMCCR-HV, 1st End, SUBJECT: Safe Replacement Material for Dioctyl Phthalate (DOP). Dated 11 April 1990.

b. Guiney, P.D., Acute Toxicity Assessment of Polyalphaolefin (PAO) Synthetic Fluids, Proc. Symposium on Synthetic and Petroleum Based Lubricants, Div. of Petroleum Based Chemistry, American Chemical Society, Las Vegas, NV, 28 March-2 April 1982, pp 381-389.

c. Memorandum, SMCCR-RST-C, SUBJECT: Mutagenicity Testing of Emery 3004. Dated 22 Aug 1990.

d. Memorandum, SMCCR-RST, Subject: Mutation Tests of Emery 3004.

e. Integrated Laboratory Systems, Rodent Bone Marrow Micronucleus Test. Project Number ILS A052, 31 Oct 1991.

2. The Army Material Command has requested approval for the use of Emery 3004 as a substitute for dioctyl phthalate (DOP) in filter test apparatus. Elements of the Chemical Research Development and Engineering Center (CRDEC) at Aberdeen Proving Ground have had approval for limited uses of Emery 3004 since April 1990 (ref 1a). Final Army-wide approval was delayed until the results from toxicology studies were available. These data and recommendations are summarized below.

3. Summary of Toxicity Data - Emery 3004.

a. Structure. Emery 3004 is a hydrogenated polyalphaolefin (PAO). It is formed by polymerizing decene-1, a 10 carbon alpha olefin. As these 10 carbon sub-units polymerize, the viscosity of the PAO increases. The composition of polymers with a viscosity of 2 centistokes (cst) is 90% of the 20 carbon dimer and 10% of the trimer. Emery 3004 has a viscosity of 4 cst and is composed of the 30 carbon trimer (85%) and the 40 carbon tetramer (15%). These compounds have found widespread use as synthetic engine and gear oils and industrial lubricants and greases.

b. Acute Toxicity. The acute toxic effects of PAOs with viscosities of 2 cst and 8 cst were described by Guiney (ref 1b). These compounds exhibit low systemic toxicity by the oral and dermal routes, with LD50 values in the 2000-5000 mg/kg range. Acute inhalation tests with the 2 cst material indicated a 4 hour LC50 of approximately 1170 mg/m^3. Since PAOs have a very low vapor

pressure these test atmospheres were generated with an atomizer to create an aerosol mist. It is unlikely that vapor concentrations approaching this level would be generated in the workplace. Tests in laboratory animals also showed that Emery 3004 did not irritate the eyes and skin and it did not cause sensitization of the skin.

c. Mutagenicity Tests. Studies sponsored by the Army evaluated the mutagenic potential of Emery 3004. This substance was not mutagenic in tests with *Salmonella typhimurium*(ref 1c) and was negative for chromosomal changes in *Drosophila melanogaster* (ref 1d). Tests for genotoxicity in mice were also negative (ref 1e).

4. Recommendation. Based on the relatively low order of toxic effects exhibited by Emery 3004, the absence of demonstrated mutagenic activity and the relatively low exposure potential, recommend approval for the use of this substance as a replacement for dioctyl phthalate in filter test apparatus.

5. POC for this action is Dr. Glenn J. Leach, phone 410-671-3980/3627.

FOR THE COMMANDER:

Encls
nc

MAURICE H. WEEKS
Chief, Toxicology Division

SGPS-PSP (SMCCR-CMH/15 Mar 91) (40-5e) 1st End LTC Broadwater/ DSN 289-0125
SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

APR 8 1991

HQDA (SGPS-PSP), 5109 Leesburg Pike, Falls Church, VA 22041-3258

FOR Commander, U.S. Army Environmental Hygiene Agency, ATTN: HSHB-MO-T, Aberdeen Proving Ground, MD 21010-5422

1. Request the U.S. Army Environmental Hygiene Agency coordinate with the appropriate Chemical Research, Development, and Engineering Center (CRDEC) technical personnel to acquire necessary data to prepare a recommended position for this office concerning the toxicity clearance for the subject test material. Direct coordination between the CRDEC POC and assigned reviewer is authorized.

2. Request the recommended position reach this office no later than 22 May 91. Point of contact for this office is LTC William T. Broadwater, Health Hazard Assessment Coordinator, DSN 289-0125 or commercial (703) 756-0125.

FOR THE SURGEON GENERAL:

Encls
nc

for RONALD R. BLANCK
Brigadier General, Medical Corps
Director, Professional Services

CF:
CDR, AMC, ATTN: AMCSG/AMCDE-XS
CDR, HSC, ATTN: HSCL-P
CDR, MRDC, ATTN: SGRD-PLC
CDR, CRDEC, ATTN: SMCCR-CMH

DEPARTMENT OF THE ARMY
U.S. ARMY CHEMICAL RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MARYLAND 21010-5423

REPLY TO
ATTENTION OF

SMCCR-CMH (40-5e) 15 March 1991

MEMORANDUM THRU Commander, U.S. Army Materiel Command, ATTN: AMCSG, 5001 Eisenhower Avenue, Alexandria, VA 22333-0001

FOR HQDA (SGPS-PSP), 5111 Leesburg Pike, Falls Church, VA 22041-3258

SUBJECT: Request for Approval of Emery 3004 as an Army-Wide Substitute Material for Dioctyl Phthalate (DOP)

1. Request your office approve the use of Emery 3004, a mix of polyalpha olefins, as an Army-wide substitute for DOP in penetrometer filter testing. A Material Safety Data Sheet (MSDS) is attached (encl 1).

2. Dioctyl phthalate is used to perform leak testing of filters, not only in the government, but, also, in private industry. However, DOP is considered a suspect carcinogen, and its use by the Army has been restricted.

3. After a three year study at USACRDEC, researchers have determined Emery 3004 to be the best prospect for a substitute of DOP.

4. Emery 3004 can replace DOP in "hot" or "cold" smoke test machines, without machine modification, and will meet or exceed military test specifications. Both compounds were analyzed side-by-side in July 1990, and oxidation levels for both indicated comparable pyrolysis effects. Specific Army equipment which can use Emery 3004 are Q-127 (TDA-100), Q-107, and Q-127 hot smoke machines, and the M14 mask face-fit machine.

5. Toxicological research to date indicates Emery has no mutagenic potential. The MSDS reveals a high LC50 of 4680 milligrams per cubic meter of air. In August 1990, Ames assay series tests were negative for mutagenicity (encl 2). Other tests in process are:

a. A recessive sex-linked mutation study in fruit flies (Drosophilia).

b. A micronucleus test in mice (the contract is being negotiated).

c. An industrial hygiene air monitoring study documenting worker exposure to Emery 3004 at the Q127 hot smoke machine operation (a "worst" case situation) at CRDEC.

6. Results of these tests will be forwarded for toxicological review upon request.

7. No further funds are available to CRDEC to perform testing beyond that indicated above. Funding and research to identify and test Emery 3004 as a safe, direct, cost-effective replacement for DOP has spanned over three years. Replacing DOP with Emery 3004, without machine modification, should yield a considerable savings to the U.S. Army in terms of hardware, manpower, and uninterrupted testing, and remove the potential for exposure to a suspect carcinogen/mutagen (i.e., DOP).

8. The point of contact for this office is Mr. Timothy W. Williams, Senior Industrial Hygienist, SMCCR-CMH, DSN 584-2318.

FOR THE COMMANDER:

Joseph Karwatka

2 Encls
as

JOSEPH KARWATKA
MAJ, MS
Chief, Health and Veterinary
Services Office

CF:
Cdr, USAMCCOM (AMSMC-SG), Rock Island, IL 61299
Cdr, USAEHA, (HSHB-MO-T), ATTN: Mr. Leach, APG, MD 21010-5422
SMCCR-RSP-P (Mr. Carlon)

SMCCR-RSL (70-1p) 11 July 1990

MEMORANDUM FOR SMCCR-RSP-P (Mr. Hugh R. Carlon)

SUBJECT: Analysis of DOP/Emery Samples

1. On 27 April 1990, a group of samples of dioctylphthalate (DOP) and "Emery 3004" was received by Analytical Research Division, Research Directorate, for analysis. The samples were either unheated, "fresh," or heated in a container for up to 110 hours at 160° C to 170° C. Analytical Research Division was tasked to analyze for any changes in the two types of samples due to the heating procedure. The samples examined are listed below:

TABLE 1

SAMPLES FOR DOP/EMERY ANALYSIS

Sample #	Type	Hr. Treated	Container
HC/MG-1	DOP	Fresh	Glass
HC/MG-2	DOP	100	Glass
HC/MG-3	Emery 3004	Fresh	Glass
HC/MG-4	Emery 3004	110	Glass
HC/MG-5	Emery 3004	16	Poly-E
HC/MG-6	Emery 3004	32	Poly-E
HC/MG-7	Emery 3004	80	Poly-E

2. Samples -1, -2, -3, and -4 were analyzed by inductively coupled plasma (ICP) emission spectrometry for the presence of iron and copper and changes in oxidation. Samples -1, -2, -3, and -4 were analyzed by infrared (IR) spectroscopy for any gross differences between fresh and long term heating effects. All samples (-1 through -7) were analyzed by gas chromatography/mass spectrometry (GC/MS) for changes with aging.

3. Analysis of the first four samples by ICP did not yield detectable levels of iron or copper in solution. The levels of oxidation, if they exist, were below the detection limit of < 50 p.p.m., where p.p.m. is noted as ug./g. solution. The data is summarized in Table 2.

TABLE 2

Sample #	Fe	Cu	Oxidation
HC/MG-1	BDL	BDL	< 50 p.p.m.
HC/MG-2	BDL	BDL	< 50 p.p.m.
HC/MG-3	BDL	BDL	< 50 p.p.m.
HC/MG-4	BDL	BDL	< 50 p.p.m.

BDL $\leq$ 10 p.p.m. Fe
BDL $\leq$ 8.7 p.p.m. Cu

3. IR analysis of the neat materials revealed that the two DOP samples (HC/MG-1 and HC/MG-2) were the same and were identical to a standard sample of Di(2-ethylhexyl)phthalate. The two "Emery" samples examined (HC/MG-3 and HC/MG-4) were similar; however, the sample heated to 110° C showed a weak band at 1722 cm^{-1} which may be due to a C=0 moiety.

4. Two samples of DOP (one fresh) and five samples of Emery 3004 (one fresh) were analyzed by GC/MS using a HP 5985B equipped with a J&W DB-5 capillary column (30 m. x 0.25 mm.) programmed from 100-340° C. Injections were made in the split mode. The mass spectrometer was operated in both EI (70 ev) and CI (200 eV, CH4) modes.

5. The CI spectra showed MH+ ions and the $M(C_2H_5)+$ adducts for the expected analytes. The DOP samples (fresh) appeared to be rather pure (99%) dioctylphthalate (MW 390). The aged DOP contained a trace of didecylphthalate.

6. The Emery 3004 samples were essentially as reported, a mix of C_{20}, C_{30}, and C_{40} polyolefins (MW 280, 420, and 560). The aged samples showed evidence of an aldehyde (C_{30} M/Z 436) in very low amounts (< 1%), indicative of thermal decomposition (oxidative pyrolysis) -- Ci MH+ = 437, $M(C_2H_5)+$ = 465. There were traces of DOP in all Emery samples except the fresh one. Since the Emery samples were analyzed before the DOP samples, the DOP was probably inherent in the samples as received by Analytical Research Division.

J. Michael Lochner

J. MICHAEL LOCHNER
Acting Chief, Methodology Research Group

SMCCR-RST-C 22 August 1990

Memorandum To: Hugh R. Carlon

Subject: Mutagenicity Testing of Emery 3004

The compound Emery 3004 was tested (Toxicology Division, CRDEC) for mutagenic potential in the Ames system and was found to be negative.

The compound as supplied , a clear viscous fluid resembling mineral oil, was emulsified in 1% Triton X 100 in distilled water at a concentration of 100,000µg/mL and tested at concertrations of 1, 10, 100, 1000 and 10,000µg/petri plate. The negative control, 1% Triton X 100 in distilled water, was also used in preparing the dilutions for testing. The four standard Ames strains (TA97, TA98, TA100 and TA102) were used in the plate incorporation assay. Testing was done both with and without metabolic activation using arochlor 1254 induced rat liver S9.

Although the Ames Test is currently perceived as the backbone of mutagenicity testing, it should not be used independantly in estimating human risk factors. If one uses the results of a carefully selected battery of test protocols, however, human risk assessment becomes feasable.

Fred K. Lee, Jr.

TIER APPROACH - MUTAGENICITY TESTING

TIER I: Designed to show primary capacity of the test compound for genotoxic effects at a minimal cost. Screening of compounds for more complex costly test procedures can be accomplished in this tier, but results should not be used to estimate risk to mammalian systems.

Gene mutation: **(Do one of these three)** (The Ames is most frequently done)

1. **Prokaryotic Microbe:**

   Ames Assay: With and without metabolic activation (aroclor 1254 induced rat liver S9) and with four standard test strains.

2. **Eukaryotic Microbe:** All done with and without metabolic activation.

   Saccharomyces cerevisiae or (This can be add to the Ames for a minor cost increase)
   Neurospora crassa or
   Aspergillus nidulans

3. **Mammalian Cells:**

   CHO/HGPRT or
   V79/HGPRT or
   L5178Y/TK

Chromosomal Aberrations:

Cytogenetic Tests in cultured mammalian cells: Such as human lymphocytes.

Primary DNA Damage:

Sister Chromatid Exchange in cultured mammalian cells: Human cells may be used.

TIER II:

Gene Mutation: In vivo and host mediated assays such as those recommended at this level usually are considered in making mutagenicity risk assessments in mammalian systems.

Sex Linked Recessive Lethal Test - Drosophila melanogaster (BASC) or
Cell Transformation Assay: Mammalian somatic cells in culture, with and without metabolic activation.

Chromosomal Aberrations:

Cytogenetic Test in mammals or
Micronucleus Test in mice.

Primary DNA Damage -

Unscheduled DNA Synthesis in mammalian cells in culture or
Sister Chromatid Exchange in mammals

TIER III: The test protocols at this level are more costly, longer term, in vivo studies and should be used to confirm results of the less costly in vitro studies of the lower tiers. Information accumulated from the lower tiers should indicate which of these in vivo studies to use. Because they are long term fully in vivo mammalian studies they are usually relied on more heavily in assessing risk to humans. This tier may range from 80 to 200K depending on which test is indicated by the results of Tiers I & II.

Lung Adenoma In Mice - Use when a carcinogen is indecated from lower tier tests.

Dominant Lethal Mutation in Rats: This test shows germ cell mutations usually resulting from chromosome anomalies and should be used when chromosome aberrations are indicated by the more economical protocols.

Heritable Translocations in Rats: This test demonstrates balanced reciprocal translocations and should be used when chromosome aberrations are indicated by the lower tier studies.

Specific Locus Test in Mice: This test demonstrates mutations in germ cells usually of the piont mutation types. It should be used to confirm lower tier tests when point mutations are indicated.

SMCCR-RST-C (7-9a)

MEMORANDUM FOR Director, Compliance Management Directorate,
ATTN: SMCCR-CMH (T. Williams)

SUBJECT: Mutation Tests of Emery 3004

1. The enclosed report covers the Drosophila Mutation Tests of Emery 3004.

2. A Drosophila sex-linked recessive lethal mutation test was conducted on Emery 3004, a synthetic aliphatic hydrocarbon. The test was run at two dose levels, along with appropriate controls. The mutation results, as tested, classified Emery 3004 as a non-mutagen in our assay system.

3. The point of contact for this study is Mr. Dale Heitkamp, SMCCR-RST-C, extension 5-4101.

FOR THE DIRECTOR:

Harry Salem

Encl

HARRY SALEM
Chief, Toxicology Division

CF:
SMCCR-RSP-P (Hugh Carlon)

Drosophila Mutation Tests of Emery 3004

1. Testing Principle.

The test used is the sex-linked recessive lethal test in Drosophila melanogaster (fruit fly) as outlined in the Federal Register (1). The test measures the occurrence and frequency of lethal mutations, both point mutations and small deletions in the germ cell line of the fruit fly. This test is a forward mutation assay capable of screening for mutations at about 800 loci on the x-chromosome which represents about 80 percent of all chromosome loci. The x-chromosome represents approximately one-fifth of the total genome of the fly.

In this Muller-5 testing technique (2), wild type male flies are dosed and mated to appropriate Muller-5 females. The resulting female offspring are mated individually to their brothers, and in the next generation the progeny are scored for phenotypically wild type males. The absence of these males indicates that a sex-linked recessive lethal mutation has occurred.

2. Test Compound.

The compound used in this test was Emery 3004, a synthetic aliphatic hydrocarbon, from Emery Division of the Quantum Chemical Corporation of Cincinnati, Ohio.

3. Fruit Flies

The following two strains of fruit flies, Drosophila melanogaster, were used in this mutation test;

a. Wild Type. A wild type stock with a very low spontaneous mutation frequency. Phenotypically the flies have round red colored eyes.

b. Basc. Muller-5. A strain used for detecting x-chromosome lethal mutations. The flies have two inversions in the x-chromosome which inhibits cross-overs. Phenotypically the flies have apricot colored bar eyes.

4. Toxicity Range Finding.

Preliminary range finding toxicity tests were conducted by dissolving the test compound in 0.1 % triton X-100 and diluting it in 1.2 % sucrose solution. The diluted solutions, placed on fiberglass filter pads in glass tubes, were feed to groups of young adult wild type male flies for 48 hours. The concentration producing approximately 50 percent mortality (LC-50) was used as the high dose. This dose showed toxicity but gave enough surviving flies for mutation testing. The low dose was selected at the concentration producing about 1 percent mortality (LC-1).

5. Dosing.

The dosing was conducted by an adult feeding method in which groups of 1 to 3 day old wild type male flies were fed the test compound dissolved in 0.1 % triton X-100 and

diluted in 1.2 % sucrose solution. The test solution was applied to fiberglass filter pads in plastic culture tubes. The young wild type male flies were feed for 48 hours while being held in an enviornmentally controlled incubator. The flies were then held an additional 24 hours, with normal food, to determine delayed toxic effects prior to the mutation testing.

A positive control of methylmethane sulfonate was tested along with appropriate negative controls of 1.2 % sucrose solutions.

6. Mutation Test Procedure.

Groups of 400 surviving dosed wild type male (P1) flies were mated individually to sequential groups of Muller-5 virgin females (P1) every 2 to 3 days for four broods to cover the germ cell cycle. The female offspring (F1) were then mated individually to their brothers (F1). In the next generation (F2) the progeny from each dose group were scored for phenotypically wild type (round red-eyed) males. Absence of these males indicates that a sex-linked recessive lethal mutation has occurred.

7. Mutation Scoring.

The following scoring procedures were used;

a. Tubes containing two or more wild type red eyed male flies were scored as negative, indicating that no mutation occurred.

b. Tubes containing 20 or more offspring, but no wild type red eyed males were scored as positive, indicating that a mutation had occurred. This was confirmed by remating to the next generation (F3) and rescoring.

c. Tubes containing less than 20 offspring and one or less wild type red eyed males were scored as questionable and retested by back-crossing to the next F3 generation and their progeny rescored.

8. Mutation Criteria.

The following criteria was used to determine if a compound is a significant mutagen.

a. The significance test developed by Kastenbaum and Bowman (3); testing the effectiveness of treatments in increasing the mutation frequency significantly above the spontaneous rate.

b. An increase of twice the spontaneous mutation frequency in conjunction with a dose response relation is considered a positive mutation response by Wurgler etc. (4).

c. Results of a 1 % or more mutation rate above the background rate can be considered mutagenic for Drosophila as described by Auerback in his article on mutation testing (5).

9. Mutation Results.

The mutation results are shown in table 1. The compound, Emery 3004, as tested was classified as a non-mutagen in this test system when compared to the previous criteria for mutagenicity. Only one confirmed mutation was seen in the low dose group, but it was not significant by the above criteria. This classified the compound as a non-mutagen as tested in this assay system.

The negative controls tested as non-mutagens with no mutations found in any of the tubes. The positive control gave enough mutations to classify it as a positive mutagen in this assay. These control results indicated that the assay system did work in our laboratory in detecting mutations.

Table 1. Mutation Results with Emery 3004 in the Sex-Linked Recessive Lethal Mutation Test in The Drosophila (Fruit Fly).

Concentration, Emery 3004	Number of Dosed Matings Tested	Number of Confirmed Mutations
10.0 %		
Brood-1	400	0
Brood-2	400	0
Brood-3	400	0
Brood-4	400	0
1.0 %		
Brood-1	400	0
Brood-2	400	1
Brood-3	400	0
Brood-4	400	0
Negative Control (*) 1.2 % Sucrose		
Brood 1-4	3373	0
Positive Control (*) Methylmethane Sulfonate		
Brood 1-4	960	149

(*) Includes results from previous tests.

Literature Cited

1. Federal Register, Environmental Protection Agency, "Sex-Linked Recessive Lethal Test in Drosophila melanogaster", (789.5275), Rules and Regulations, vol. 50, no. 188, 27 September 1985

2. Wurgler, F. E., Sobels, F. H. and Vogel, E. Drosophila as an Assay System for Detecting Genetic Change. B. T. Kilby et al, (eds). pp 335-373. Handbook of Mutagenicity Test Procedures. Elsevier Scientific Publishing Company, Amsterdam. 1977

3. Kastenbaum, M. A. and Bowman, K. O. Tables for Determining the Statistical Significance of Mutation Frequencies. Mutation Res., 9, 527-549, 1970

4. Wurgler, F. E., Graf, V. and Berchtold, W. Statistical Problems Connected with the Sex-Linked Recessive Lethal Test in Drosophila melanogaster. Arch. Genet. 48, 158-178. 1975

5. Auerbach, C. The Role of Drosophila in Mutation Testing. G.E. Paget (ed). Mutagenesis in Sub-mammalian Systems. pp 13-22. University Park Press, Baltimore, MD

CLASTOGENIC STUDIES OF EMERY 3004

A clastogenic study (the Mouse Micronucleus Test) on Emery 3004 has been identified as a critical requirement and steps were taken to place this task on contract. A contract proposal, sole-sourced to Integrated Laboratory Systems (Research Triangle Park, NC), was submitted. The contract for this task is currently in the process of negotiation and assignment. The urgency of the needed data base has been expressed on several occasions, and the contractor is expected to respond with the greatest degree of expedience.

ILS

STUDY PROTOCOL

I. STUDY TITLE: Rodent Bone Marrow Micronucleus Assay

II. PROJECT IDENTIFICATION: ILS Project No. A052
Contract No. DAAA15-91D-0024

III. MANAGEMENT OF STUDY

A. Sponsor

United States Army
Chemical Research, Developement and Engineering Center
Aberdeen Proving Ground, MD 21005

B. Testing Laboratory

Integrated Laboratory Systems
P O Box 13501
Research Triangle Park, NC 27709

C. Project Officer

Hugh Carlon

D. Study Director

Paul Andrews, M.S.

E. Laboratory Personnel

Raymond R. Tice, Ph.D., Program Director
Rita Shendrikar, B.S., Research Assistant
Kaye Cummings, B.S., Quality Assurance Officer

IV. TEST ARTICLE(S) - Information to be supplied by the Sponsor

V. PROJECT SCHEDULE

Proposed Initiation Date: August 19, 1991

Proposed Completion Date: October 19, 1991

VI. APPROVAL:

Sponsor: Hugh R. Carlon Date: 9/03/91

Study Director: Paul Andrews Date: 8/19/91

APPENDIX E

STUDY TITLE
Rodent Bone Marrow Micronucleus Test

Project No.
ILS A052

Contract No.
DAAA15-91D-0024

Test Article
Emery 3004 Synthetic Hydrocarbon 4CST Fluid

ILS Repository No.
91-26

Final Report Date
October 31, 1991

Sponsor
Mr. Hugh Carlon
U.S. Army
Chemical Research, Development and Engineering Command
Aberdeen Proving Grounds, MD 21005

Testing Facility
Integrated Laboratory Systems
801-8 Capitola Dr.
Durham, NC 27713

SUBMITTED BY

INTEGRATED LABORATORY SYSTEMS

PO Box 13501, Research Triangle Park, North Carolina 27709.

APPENDIX E

TABLE OF CONTENTS

STUDY TITLE
Rodent Bone Marrow Micronucleus Test

PREFACE

Cytogenetic testing with Emery 3004 synthetic hydrocarbon 4CST fluid (ILS No. 91-26), employing the Rodent Bone Marrow Micronucleus Assay, is presented in this report. The first part of the report contains a study description, criteria for test data acceptance, methods employed in data evaluation, and a summary of test results. The second part of the report contains the Appendix which provides specific test results. Items I through V of the Appendix identify the sponsor, test article information, bioassay information, project management, study test results, and interpretation of the results. The summarized study results are given in Tables 1 and 2.

Original experimental data and statistical analysis printouts are archived at Integrated Laboratory Systems (ILS), 801-8 Capitola Drive, Durham, NC 27713 (919/544-4589) for a period of five years from the date of report submission. Stained and coded slides will be held in storage as long as the quality of the preparations affords evaluation. Copies of these records will be made available to the sponsor upon request.

The study was conducted in accordance with Good Laboratory Practice regulations as promulgated by the U.S. Environmental Protection Agency (40CFR Part 160).

1.0 INTRODUCTION

During the last decade, the analysis of micronuclei (MN) has gained increased popularity as an alternative to classical chromosomal aberration analysis for detecting clastogenic agents (1-3). The scoring of MN is less subjective and less time consuming than the analysis of chromosomal aberrations, permitting a greater number of cells to be examined for the same extent of effort. This in turn results in greater statistical power. Furthermore, since MN are formed from both acentric chromosome fragments and from lagging, intact chromosomes (1,3), this technique is the most reliable method currently available for evaluating the potential of a chemical to induce either clastogenic and/or aneugenic damage. Among the various in vitro and in vivo MN assays used to detect genotoxic chemicals, the rodent bone marrow micronucleus test is the most commonly used (1,3). The assay is easily conducted in mice or rats by evaluating the frequency of MN in immature erythrocytes [polychromatic erythrocytes (PCE)] scored in bone marrow (mice or rats) or peripheral blood (mouse only) preparations (1,4-6). The product of recent cell divisions, these

enucleated cells are abundant, easily recognizable, and have a lifetime of approximately two days before maturing into normochromatic erythrocytes (NCE). In the rodent bone marrow assay, the test chemical can be administered by any exposure route used in standard toxicology studies and the exposure regimen can range from single, acute exposure to chronic exposures.

As with other cytogenetic techniques for evaluating genotoxic damage in bone marrow, the timing for sample collection in relation to treatment is a critical parameter. For any agent, the optimal bone marrow sampling time for micronucleated PCE (MN-PCE) induction depends on the mechanism of action, pharmacokinetic considerations, and the extent of erythropoietic suppression. Due to agent-specific differences in peak micronucleus induction, multiple sampling times between 24 and 72 hours are generally recommended after a single treatment to avoid a false-negative conclusion (1,3). A successful method for eliminating the necessity for multiple sampling times is to increase the number of treatments (7). Based on the kinetics of erythropoiesis and the metabolic/distribution properties of most chemicals, a single treatment on three consecutive days offers the greatest opportunity for eliminating the need for multiple sample times. A single sample time protocol minimizes animal usage, decreases the time needed for data collection and simplifies the statistical analysis.

Although two sexes are often used in most toxicological studies, a large data base is available demonstrating that under similar experimental conditions, male and female mice exhibit quantitative but not qualitative differences in response (8). On the other hand, species differences in sensitivity are much more common. For example, chemicals which induce tumors in one rodent species but not another are fairly common. Thus, greater sensitivity accompanies the use of two strains rather than two sexes of one strain.

2.0 OBJECTIVE

The objective of this study was to test the ability of Emery 3004 synthetic hydrocarbon 4CST fluid and/or its metabolites to induce micronuclei in bone marrow cells of male B6C3F1 mice.

3.0 MATERIALS AND METHODS

3.1 Test Article

Emery 3004 Synthetic Hydrocarbon 4CST Fluid was received from the U.S. Army/CRDEC and was stored at room temperature in the ILS Chemical Repository. Chemical safety and handling information was not provided and therefore the test article was treated as a

hazardous chemical. Based on information supplied by the sponsor, the vehicle selected was corn oil.

ILS Repository No. - 91-26
Sponsor Sample I.D. - Emery 3004 Synthetic Hydrocarbon 4CST Fluid
Physical Description - clear liquid

3.2 Chemicals and Reagents

The chemicals and reagents used in this study were obtained from the following commercial sources:

Chemical	Source	Lot No.
acridine orange	Sigma	67F-3686
corn oil	Sigma	80H0835
dimethylbenz[a]anthracene	Kodak	G16A
fetal bovine serum	Irvine	30000562
methanol	Fisher	902792
sodium phosphate monobasic	Sigma	37F-0382
sodium phosphate dibasic	Sigma	127F-0130

3.3 Range-Finding Experiment Protocol

The purpose of the range-finding (RF) experiment is to determine the maximum dose for the study. The maximum evaluated dose is that dose which:

a) is the highest dose that induces less than 40% mortality and does not lead to obvious physical stress, or

b) when administered, the dose results in a significant depression of polychromatic erythrocytes (PCE) (not to exceed a 70% depression of the average control value) in the bone marrow, or

c) is the maximum dose which can be administered as a homogeneous suspension without exceeding 2000 mg/kg.

The maximum dose is determined by the following procedure: Using 5 animals/group, mice are treated by intraperitoneal (IP) injection (dose volume = 0.4 ml.) on 3 consecutive days with 0.5x, 1x, and 2x the known, appropriate LD50. If LD50 or other mortality data are unavailable, the initial doses tested are generally 200, 1000, and 2000 mg/kg. Mortality is checked twice daily until animal sacrifice. Forty-eight hours after administering the final dose, surviving mice are killed by CO_2 asphyxiation, and bone marrow smears are prepared. The percentage of PCE in bone marrow is determined. Based on the results obtained, an additional RF study may be conducted using either a higher or lower dose range. Once the maximum dose is established, two additional doses at 0.5x

and 0.25x the maximum dose are selected for testing.

3.4 Experimental Protocol

Three IP treatments (dose volume = 0.4 ml) at 24-hour intervals are followed by a single sampling time 24 hours after the final treatment. Mice are killed by CO_2 asphyxiation, assigned random numbers and bone marrow smears (2 per animal) are prepared.

3.5 Positive Control

A positive control is selected for its ability to induce micronuclei in polychromatic erythrocytes. The positive controls used for mice are mitomycin C (MMC) at 0.2 mg/kg for water-soluble compounds and dimethylbenz[a]anthracene (DMBA) at 12.5 to 25.0 mg/kg, depending on the species, for water-insoluble compounds. DMBA suspended in corn oil was used as the positive control in this study.

3.6 Bone Marrow Slide Preparation

Immediately following CO_2 asphyxiation, the femur is removed. A 22G x 1" needle with a 1 cc syringe is used to push a few drops of fetal bovine serum through the bone marrow cavity, flushing the bone marrow onto a prelabelled slide. A second prelabelled slide is inverted and placed flush to the first. The two slides are rubbed together with a circular motion until the bone marrow is evenly dispersed. The slides are pulled apart and air-dried. After fixing in methanol for 5 minutes and air-drying, slides are stained with acridine orange.

3.7 Micronuclei Scoring

Coded slides (2 per mouse) are scored in numerical order by two scorers. To assess if the test article induced a significant depression in bone marrow erythropoiesis (signified by a reduction in the proportion of PCEs within the total erythrocyte population), the number of PCEs among a total of 200 erythrocytes (100 erythrocytes/animal/scorer) was determined in continuous field at 1000X magnification. For micronuclei evaluation, 2000 PCEs (1000 PCEs/animal/scorer) were evaluated in continuous field at 1000X magnification for the presence of micronuclei.

3.8 Data Analysis

Data analyses are conducted using a micronucleus assay data management and statistical analysis software (9) developed by ILS

for the EPA. In this program, a one-tailed trend test uses pooled data and incorporates a variance inflation factor to account for excess interanimal variability. The trend test is used to determine if a treatment-related increase in MN-PCE frequency occurred at an alpha level of 0.05 (9,10). An analysis of variance (ANOVA) test based on pooled data is used to determine if a treatment-related difference in the percentage of PCE occurred at an alpha level of 0.05. For statistically significant results, pairwise comparisons between dose groups and the control group are conducted using the appropriate one-tailed (MN) or two-tailed (%PCE) Pearson Chi-Square test (pooled data) to determine the minimal effective dose. A Pearson Chi-Square test is used to evaluate the significance of the positive control MN-PCE and %PCE data.

3.9 Data Acceptance Criteria

A minimum of three surviving mice per dose group is required for test data acceptance. The mean number of MN-PCE in the control group must not exceed 4 per 1000 PCE. The positive control must induce a significant increase in the number of MN-PCEs relative to the negative control.

4.0 RESULTS AND DISCUSSION

4.1 Range-Finding (RF) Experiment

The RF experiment for Emery 3004 synthetic hydrocarbon 4CST fluid was conducted using doses of 200, 1000, and 2000 mg/kg (Table 1). No mortality occurred at any of the doses tested and the percentage of PCE was not significantly decreased. Based on these data, the highest dose of the test article selected for micronucleus testing was 2000 mg/kg.

4.2 Micronucleus Experiment

The doses tested were 500, 1000, and 2000 mg/kg (see Table 2 for group summary data). Over this dose range, treatment with Emery 3004 synthetic hydrocarbon 4CST fluid did not result in a significant increase in MN-PCE ($P = 0.961$). The percentage of PCE was not significantly depressed ($P = 0.924$). One mouse at 1000 mg/kg died during this experiment. The positive control, DMBA at 25 mg/kg, induced a significant increase in MN frequency ($P < 0.001$) and significantly depressed the percentage of PCE ($P < 0.001$).

5.0 CONCLUSIONS

Multiple treatments with Emery 3004 synthetic hydrocarbon 4CST fluid did not result in a significantly increased frequency of MN-PCE in the bone marrow of male B6C3F1 mice. In addition, the test article did not significantly depress the percentage of PCE in either experiment.

6.0 REFERENCES

(1) Heddle, J.A., Hite, M., Kirkhart, B., Mavrournin, K., MacGregor, J.T., Newell, G.W. and Salamone, M.F. (1983) The induction of micronuclei as a measure of genotoxicity. A report of the U.S. Environmental Protection Agency Gene-Tox Program. Mutat. Res. 123: 61-118.

(2) Tice, R.R. and Ivett, J.L. (1985) Cytogenetic analysis of bone marrow damage. In: R.D. Irons (ed.) Toxicology of the Blood and Bone Marrow, Raven Press, NY, pp. 119-140.

(3) MacGregor, J.T., Heddle, J.A., Hite, M., Margolin, B.H., Ramel, C., Salamone, M.F., Tice, R.R. and Wild, D. (1987) Guidelines for the conduct of micronucleus assays in mammalian bone marrow erythrocytes. Mutat. Res. 189: 103-112.

(4) Schmid, W. (1976) The micronucleus test. In: A. Hollaender, (ed), Chemical Mutagens: Principles and Methods for Their Detection, Vol. 4, Plenum, NY, pp. 31-43.

(5) MacGregor, J.T., Wehr, C.M. and Gould, D.H. (1980) Clastogen-induced micronuclei in peripheral blood erythrocytes: the basis of an improved micronucleus test. Environ. Mutagen. 2: 509-514.

(6) Schlegel, R. and MacGregor, J.T. (1982) The persistence of micronuclei in peripheral blood erythrocytes: Detection of chronic chromosome breakage in mice. Mutat. Res. 104: 367-369.

(7) Tice, R.R., G.L. Erexson, C.J. Hilliard, J.L. Huston, R.M. Boehm, D. Gulati, and M.D. Shelby (1990) Effect of treatment protocol and sample time on the frequencies of micronucleated polychromatic erythrocytes in mouse bone marrow and peripheral blood. Mutagenesis 5: 313-321.

(8) Collaborative Study Group for the Micronucleus Test. Sex differences in the micronucleus test. Mutat. Res. 172: 151-163, 1986.

(9) Micronucleus Assay Data Management and Analysis System, Version 1.4 (1990) U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, NV.

(10) Margolin, B.H. and Risko, K.J. (1988) The statistical analysis of in vivo genotoxicity data. Case studies of the rat hepatocyte UDS and mouse bone marrow micronucleus assays, in "Evaluation of Short Term Tests for Carcinogens", Oxford University Press, Oxford, UK, pp 29-43.

TABLE 1: MORTALITY DATA AND GROUP MEAN %PCE FOR MOUSE RANGE FINDING EXPERIMENT ON TEST ARTICLE EMERY 3004 SYNTHETIC HYDROCARBON 4CST FLUID (ILS # 91-26).

DOSE[a] (mg/kg)	DAYS[b] 1	2	3	4	5	TOTAL DEAD	%PCE MEAN	SEM	N
0.0	0	0	0	0	0	0	59.2	5.30	5
200.0	0	0	0	0	0	0	56.8	2.88	5
1000.0	0	0	0	0	0	0	59.1	2.93	5
2000.0	0	0	0	0	0	0	51.0	0.88	5

N = Number of animals scored.
[a] Five animals used per dose group.
[b] Mice were treated by IP injection on days 1 through 3.

TABLE 2: GROUP MICRONUCLEI AND %PCE DATA FOR MICE TREATED WITH EMERY 3004 SYNTHETIC HYDROCARBON 4CST FLUID (ILS # 91-26).

DOSE (mg/kg)	MN-PCE/1000 PCE[a] MEAN	SEM	%PCE[b] MEAN	SEM	N
DMBA-25	*10.90	2.40	*26.6	2.29	5
0	1.80	0.75	39.5	2.61	5
500	2.60	0.43	38.3	3.67	5
1000	2.38	1.20	37.6	4.86	4
2000	1.00	0.27	37.0	3.51	5
TREND P-VALUE+	0.961		0.924		

[a] Group mean frequency of MN-PCE per 1000 PCE and standard error of the mean among mice. Data based on 2000 PCE scored per mouse.

[b] Group mean percent PCE and standard error of the mean among mice. Data based on 1000 erythrocytes scored per mouse.

+ One-tailed trend or ANOVA test P-value for MN and %PCE data, respectively. Data analysis based on pooled cells.

* P-value significant at alpha = 0.05.

APPENDIX

Rodent Bone Marrow Micronucleus Test

Test Article: Emery 3004 Synthetic Hydrocarbon 4CST Fluid

ILS Project No.: ILS A052

Report Date: October 31, 1991

I. SPONSOR: U.S. Army
Chemical Research, Development and Engineering Command
Aberdeen Proving Ground, MD 21005

II. TEST ARTICLE INFORMATION

A. Identification: Emery 3004 Synthetic Hydrocarbon 4CST Fluid (ILS No. 91-26)

B. Physical Description: Clear liquid

C. Strength, Stability, Purity and Chemical Analysis: Not provided

D. Date Received: July 8, 1991

E. Handling Information: Treated as a hazardous substance, used safety goggles, impervious gloves, and respirator with an organic filter.

III. BIOASSAY INFORMATION

A. Identification: Rodent Bone Marrow Micronucleus Test

B. Protocol Approval Date: September 3, 1991

C. Study Initiation Date: August 18, 1991

D. Study Termination Date: October 31, 1991

E. Archives: Microscope slides and experiment data sheets
Micronucleus scoring data sheets
Data analysis printouts and diskettes
(All records and specimens will be archived at Integrated Laboratory Systems, 801-8 Capitola Drive, Durham, NC 27713)

IV. PROJECT MANAGEMENT INFORMATION

A. Study Director: Paul W. Andrews, M.S.

B. Research Assistant: Rita Shendrikar, B.S.

C. Program Director: Raymond R. Tice, Ph.D.

C. Quality Assurance Officer: Kaye Cummings, B.S.

V. STUDY RESULTS

Multiple treatments with the test article did not result in a significantly increased frequency of MN-PCE in the bone marrow of male B6C3F1 mice. In addition, the test article did not significantly depress the percentage of PCE.

QUALITY ASSURANCE INSPECTION STATEMENT

ILS Project No.: ILS A052
Test Article ID: Emery 3004 Synthetic Hydrocarbon 4CST Fluid
Study Title: Rodent Bone Marrow Micronucleus Test

Inspection/Audit	Date Performed	Date Reported to Study Director/Management
Dosing/Dose Calculations	09-13-91	09-13-91/10-29-91
Data Audit	10-28-91/10-29-91	10-29-91
Report Audit	10-28-91/10-29-91	10-29-91

Kaye Cummings
Kaye Cummings, B.S.
Quality Assurance Officer

10/31/91
Date

CERTIFICATION OF GOOD LABORATORY PRACTICE

ILS Project No.: ILS A052
Test Article ID: Emery 3004 Synthetic Hydrocarbon 4CST Fluid
ILS Repository No.: 91-26
Study Title: Rodent Bone Marrow Micronucleus Test

To the best of my knowledge, this study was conducted in accordance with Good Laboratory Practice regulations as promulgated by the U.S. Environmental Protection Agency (Federal Register Vol. 54, No. 158, August 17, 1989).

Reviewed by:

Raymond Tice
Raymond R. Tice, Ph.D.
Program Director

10-31-91
Date

Paul Andrews
Paul W. Andrews, M.S.
Study Director

10/31/91
Date

CERTIFICATION OF CONTRACT COMPLIANCE

ILS Project No.: ILS A052
Test Article ID: Emery 3004 Synthetic Hydrocarbon 4CST Fluid
Study Title: Rodent Bone Marrow Micronucleus Test

The contractor, Integrated Laboratory Systems, hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. DAAA15-91D-0024 is complete, accurate, and complies with all requirements of the contract.

Raymond Tice

Raymond R. Tice, Ph.D.
Program Director

10-31-91
Date

PROTOCOL DEVIATIONS

STUDY: Rodent Bone Marrow Micronucleus Test

DATE: October 31, 1991

TEST ARTICLE ID: Emery 3004 Synthetic Hydrocarbon 4CST Fluid

CONTRACT NO.: DAAA15-91D-0024

ILS PROJECT NO.: A052

DEVIATIONS:

Page 7 - RANGE-FINDING EXPERIMENT

Revised Third Paragraph:

Using 5 animals/group, test animals will be treated by IP injection on 3 consecutive days with 200, 1000 and 2000 mg/kg. At the end of the maximum exposure period (48 hours after the last injection) bone marrow smears are prepared from the survivors and the percentage of PCE in bone marrow is determined. Throughout this period, animals are checked twice daily for mortality. Based on these results, additional range-finding studies using an intermediate or lower dose range may be required.

Reason for the Deviation:

The original protocol mistakenly called for treatment by gavage.

Page 8 - SCORING

Revised Third Paragraph:

For micronuclei evaluation, 2000 PCEs* are evaluated in continuous field at 1000x magnification for the presence of micronuclei. Although a record is maintained of the number of micronuclei noted per PCE, the scored elements are the number of micronucleated cells, not the number of micronuclei.

Reason for the Deviation:

The original protocol mistakenly indicated that the scoring would be conducted at 100X magnification.

Page 10 - GOOD LABORATORY PRACTICES

Revised Paragraph:

The study was conducted in accordance with Good Laboratory Practice regulations as promulgated by the U.S. Environmental Protection Agency (Federal Register Vol. 54, No. 158, August 17, 1989).

Reason for the Deviation:

The original protocol mistakenly indicated that the study would be conducted in accordance with good laboratory practice regulations for nonclinical laboratory studies.

Submitted by:

Paul Andrews

Paul W. Andrews, M.S., Study Director

10/31/91

Date

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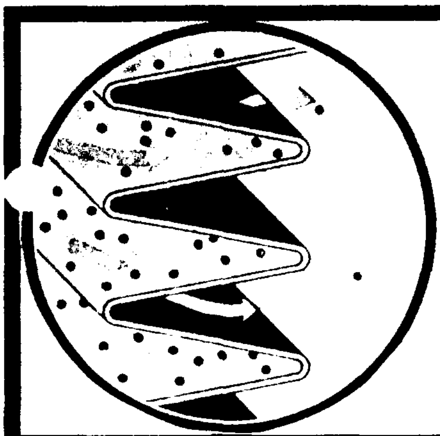
APPENDIX F

Description of the TSI, Inc., Model 8110 Automated Filter Tester



Model 8110 Automated Filter Tester

Features and Specifications

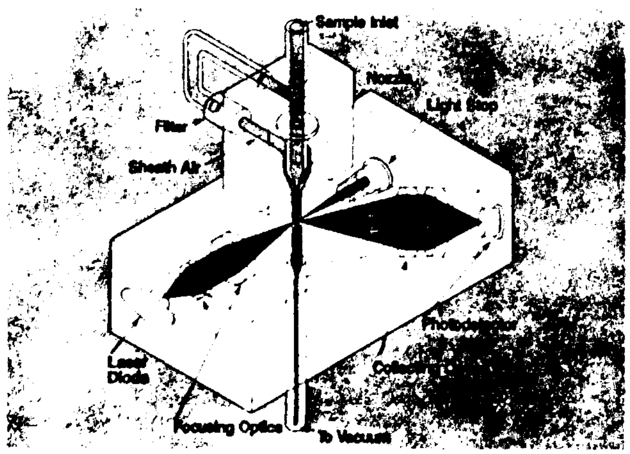
TSI Model 8110 Automated Filter Tester represents a new generation of production filter testers. The TSI tester is faster and easier to operate than presently available production filter testers and requires little operator training. It also uses TSI's solid-state photometer for top notch accuracy over its dynamic range.

The tester generates an aerosol which is used to challenge a test filter. Particle concentrations are measured upstream and downstream of the filter, with filter penetration calculated by a microprocessor. To conduct a test, the operator simply puts a canister or filter in the filter holder and pushes two buttons to close the holder. The test then runs automatically, with the penetration, flow rate and pressure drop displayed at the conclusion.

A microprocessor-based system, the Model 8110 has a self-diagnostic feature which significantly reduces operator training and the need for operator intervention during the test sequence. If a parameter is outside the specified range, the microprocessor declares the test invalid and directs the operator to the source of the problem.

TSI's unique solid-state photometer makes the system highly reliable. The photometer uses a laser diode for the light source and a photodiode as the detector. This combination of solid-state components provides high reliability and stability. TSI's unique off-axis light collection greatly reduces background light levels at the detector. The microprocessor automatically switches gains on the photometer output and corrects for background levels.

Aerosol generators are provided for both salt and oil testing.



The Model 8110 detects particles using a solid-state photometer.

Options include the Model 8111 Automated Fit Tester package which converts the Model 8110 to a respirator fit tester for use with any chamber.

Features

- ☐ Fast, reliable filter efficiency measurements
- ☐ Automated operation with minimum operator training
- ☐ Extremely accurate concentration measurements over a wide dynamic range
- ☐ Measures efficiencies to 99.99% and beyond
- ☐ Filter pressure drop and flow rate measurements
- ☐ Self-check diagnostics
- ☐ Easy accessibility in movable cabinet
- ☐ No zero and span adjustments on detector
- ☐ Printer provides hard copy output
- ☐ RS-232 data output
- ☐ Salt and oil aerosol generators

Accessories

- ☐ 102 mm filter holder for concentration verification
- ☐ Orifice plate for flow calibration

TSI

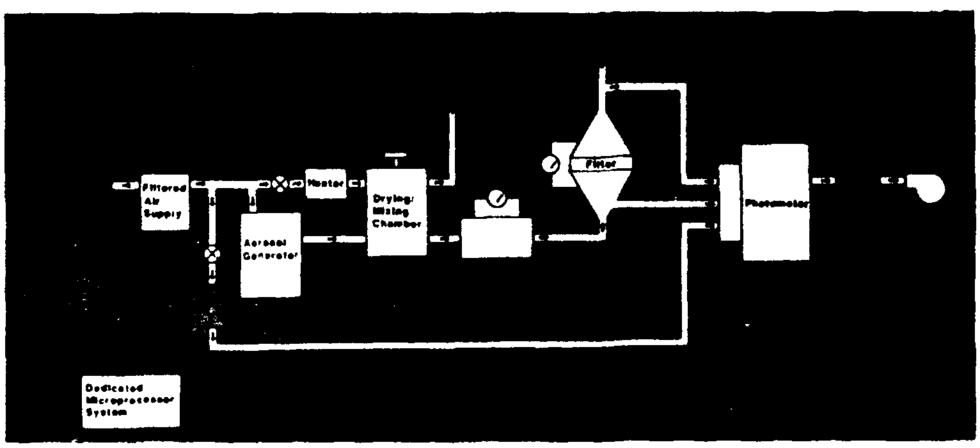
Options

☐ Model 8111 Automated Fit Tester package

Specifications

Challenge Aerosol	
Oil Generator (using DOP)	
Technique	Atomizer
Number Mean Diameter	0.20 micrometer
Geometric Standard Deviation	<1.6
Concentration	15 mg/m³ to 100 mg/m³
Salt Generator (using NaCl)	
Technique	Atomizer
Number Mean Diameter	0.10 micrometer
Geometric Standard Deviation	< 1.9
Concentration	15 mg/m³ to 100 mg/m³
Challenge Aerosol Detection	
Technique	Solid-state photometer
Sample Flow Rate	2.2 l/min
Dynamic Range	1.0 μg/m³ to 200 mg/m³
Accuracy	± 10%
Flow Measurement	
Technique	Orifice with electronic pressure transducer
Accuracy	± 2% of reading
Range	15 to 110 l/min
Pressure Measurement	
Technique	Electronic pressure transducer
Accuracy	± 0.5% of full scale
Range	0 to 15 cm H_2O
Efficiency Measurements	
Flow Rate through Media	15 to 100 l/min
Operating Range	Efficiencies to 99.99% and beyond
Automation and Data Management	Dedicated microprocessor system
Operational Requirements	
Power	115 VAC, 60 cycle, 4A or 230 VAC, 50 cycle, 2A
Compressed Air	7 cfm @ 80 psi
Physical Characteristics	
Size	30 in. H x 29 in. W x 27 in. D (76 cm x 74 cm x 69 cm)
Weight	210 lb (95 kg)

Specifications are subject to change without notice



TSI.

TSI Incorporated Industrial Test Instruments Group
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P.O. Box 64394
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Telephone: 612 490 2888
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TSI GmbH
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D-5100 Aachen,
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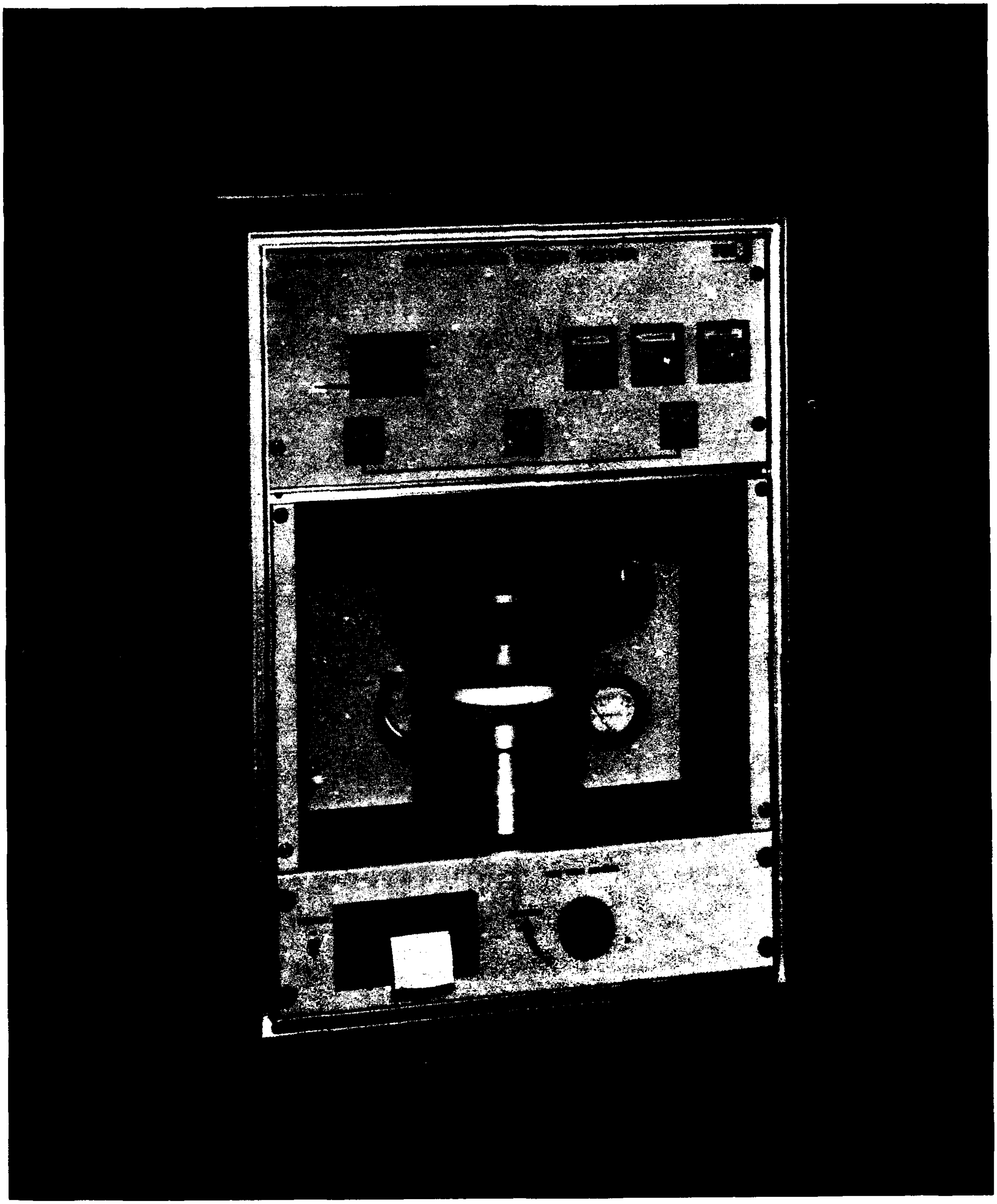
Telephone: 0241 52303 0
Telex: 83 2219 TSI D
Fax: 0241 5230349

Information taken from advertisement in public domain.



Feature Product: Model 8110 Automated Filter Tester

Beginning with this issue, each ***Industrial Test News*** will contain a special feature product section. This section will highlight in detail an Industrial Test Instruments product by focusing on the instrument's operation and features. This feature will also include schematics, illustrations, and photographs as well as other material to assist in giving you a more in-depth look at some of TSI's products and their applications.

This issue's feature product is TSI's Model 8110 Automated Filter Tester.

Introduction

The Model 8110 Automated Filter Tester fills the production filter tester niche in TSI's line of Automated Filter Testers.

The Model 8110 measures filter efficiencies by incorporating a solid-state photometer to measure aerosol concentrations upstream and downstream of a test filter. A dedicated microprocessor controls the entire testing process and performs checks on the system to ensure the tester is functioning properly. Filter flow rate, pressure drop, and percent penetration are displayed on a three-line LED display. This tester also features a loading test mode which challenges a filter over a longer period to determine loading characteristics of a filter. Solid or liquid particles can be generated with known mass concentrations. High mass concentration levels are attainable to expedite filter loading tests.

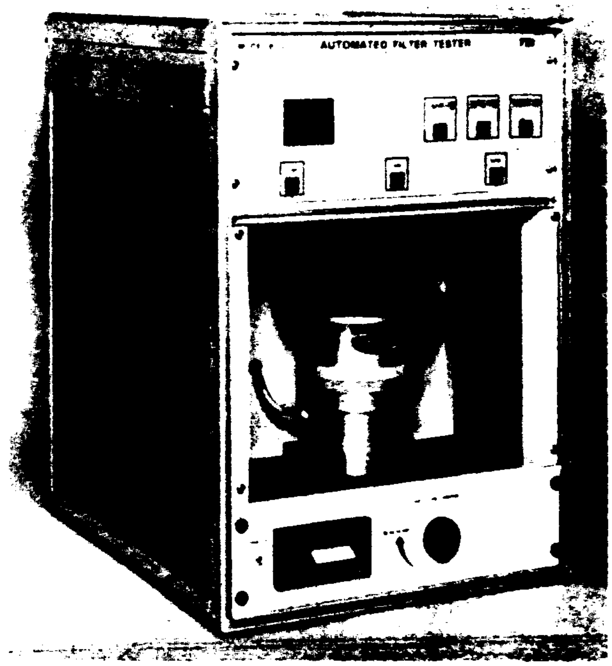


Figure 2. Model 8110 Automated Filter Tester

Tester Description

A schematic of the tester is shown in figure 1 and a photograph of the tester is shown in figure 2. The tester has five major components. These are:

1) Aerosol generation system
2) Aerosol mixing/transport system
3) Filter holder assembly
4) Particle detector
5) Microprocessor system

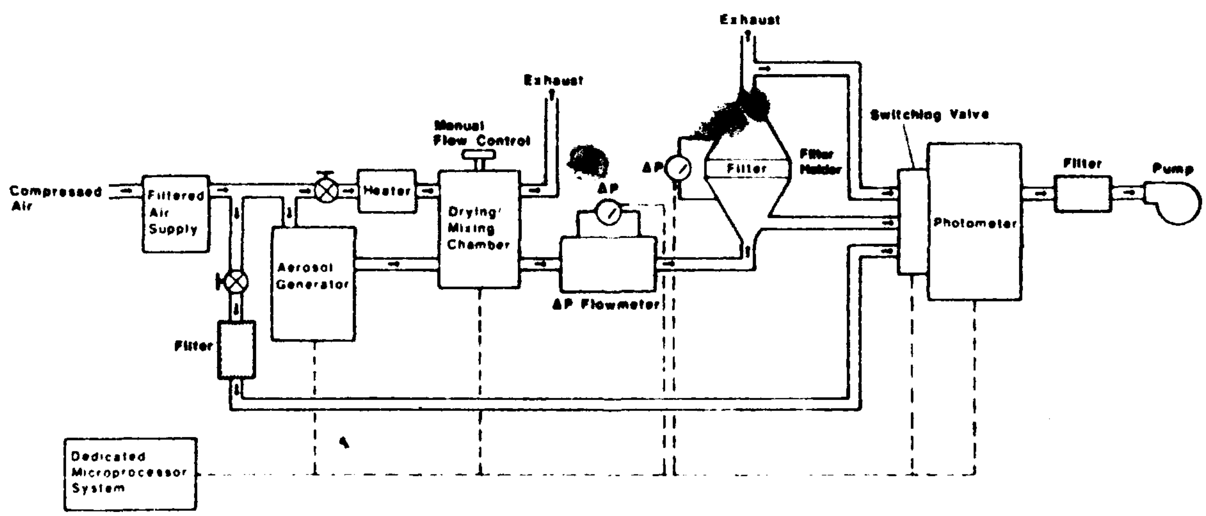


Figure 1. Schematic of the 8110 Filter Tester

Aerosol Generation System

The tester challenges a filter with a polydisperse aerosol in solid or liquid form. A compressed air nebulizer is used to generate the submicrometer aerosol used in this tester. The two particle compositions primarily used are NaCl (number mean diameter 0.1 micrometers, std. dev. < 1.9) and DOP (number mean diameter 0.2 micrometers, std. dev. < 1.6). The tester may be set for low mass concentrations (approximately 15 mg/m^3 or high mass concentrations (approximately 100 mg/m^3).

Aerosol Mixing/Transport System

The 8110 Automated Filter Tester is a pressure-type filter tester. Aerosol is forced through the filter holder by mixing the aerosol and dilution air at a slight positive pressure in a mixing chamber. This chamber also directs the flow of aerosol to either an exhaust port or to the filter holder. A special flow set-up mode allows the flow rate to be adjusted by turning a knob on the front panel of the tester. Flow rate and pressure drop of the filter holder are displayed on a real-time basis. Flow ranges from 15 to 100 l/min are obtainable through the filter holder.

Filter Holder Assembly

The filter holder is shown in figure 3. In this tester, the flow through the filter holder moves from the bottom up. The filter holder is an air operated assembly consisting of two halves. The bottom half contains the aerosol inlet port, upstream sample port, upstream pressure port, and a removable dispersion plate to mix the aerosol. The top half is connected to an air cylinder and contains the downstream pressure port and the aerosol exhaust port. The downstream sample is taken from the exhaust line downstream of the filter holder. A pressure transducer connected to the two pressure ports measures the pressure drop across the filter. The closing force exerted by the top half of the filter holder is controlled by a pressure regulator. The tester incorporates a two-hand control system to close the filter holder.

Particle Detector

A light-scattering photometer is used to make concentration measurements upstream and downstream of the filter being tested. A schematic of the photometer is shown in figure 4. Immediately after entering the photometer, the flow is split and a portion of the flow is directed through a high efficiency filter and serves as sheath air. Sheath air is used to isolate the remaining aerosol sample from the photometer body to keep the photometer clean. The aerosol sample passes through the light scattering chamber in a uniform column encased in a clean sheath air column.

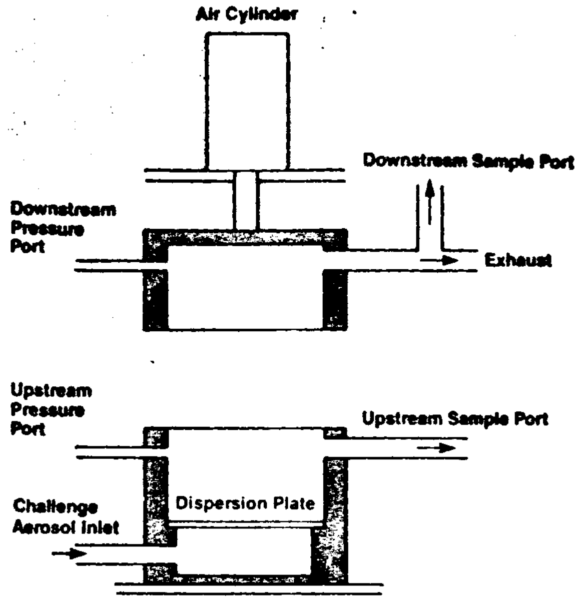


Figure 3. Filter holder assembly

A 5mw laser diode serves as the light source and is focussed through the aerosol column. A 45 degree collection optics assembly focussed onto a solid state photodetector is used to collect the scattered light. Collecting 45 degrees off-axis from the light source minimizes light scattering variations due to changes

continued on next page

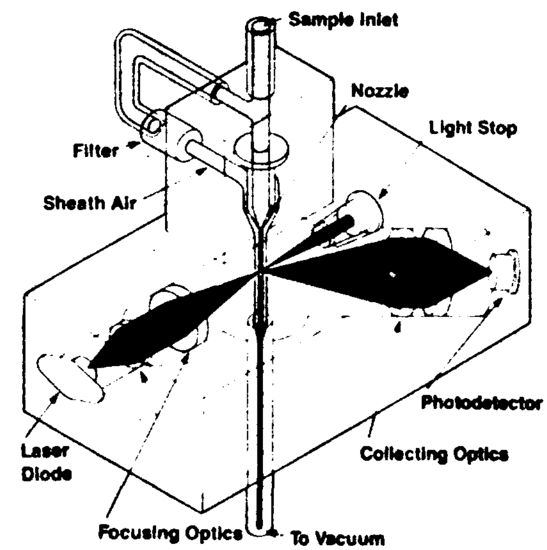


Figure 4. Photometer schematic

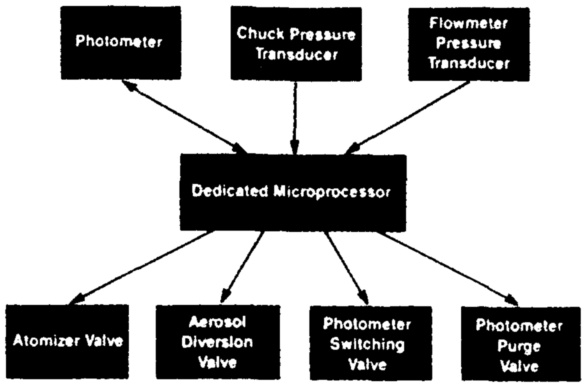


Figure 5 Microprocessor system

in particle diameter. The photometer electronics has four gain levels to amplify the detector output. This enables the microprocessor to read the output more accurately at low signal levels. The microprocessor reads the photometer output and determines the proper photometer gain setting for best readability. The photometer sensitivity enables the tester to measure filter efficiencies to 99.99% at low aerosol concentrations, and up to 99.999% at high concentrations.

Microprocessor System

A dedicated microprocessor is used to control the test, record the photometer, flowmeter, and pressure transducer outputs, and to display the results. Figure 5 shows how the microprocessor is interfaced to the filter tester. The tester has a three line LED display, each line being four characters long. Filter flow rate is displayed on the top line in l/min. Filter pressure drop is displayed on the second line in mm of H_2O. The bottom line displays percent penetration. A thermal printer is provided for hard-copy of the test data.

Operation of Tester

The Model 8110 Automated Filter Tester is easy to operate. The operator inserts a filter into the filter holder, presses two buttons to close the filter holder, and the test automatically begins. At the completion of the test, the filter holder opens automatically and the operator removes the filter and repeats the cycle.

During a test cycle, the tester first records photometer background level and stores this value to subtract from the upstream and downstream measurements. The tester then records the filter flow rate, pressure drop, and downstream concentration. After switching the photometer inlet to upstream of the filter, the tester records the upstream concentration. Percent penetration is computed and all data is displayed.

A separate switch on the front panel puts the tester into a flow set-up mode. In this mode, the test does not automatically begin when the filter holder is closed. Instead, a real-time readout of flow and pressure drop are displayed to allow the operator to be able to adjust the filter flow rate. The filter flow rate is adjusted by turning the flow control knob on the front panel. After the proper flow rate is attained, the flow set-up switch is pressed again and the test begins.

Another front panel switch puts the tester into a loading test mode. In this mode, the filter holder does not automatically open at the end of the test. Instead, the tester delays for a brief time and repeats the test cycle. This procedure will run indefinitely until the operator presses the open button on the filter holder. This mode is used to record filter loading characteristics.

For more information on the Model 8110 Automated Filter Tester, write TSI Incorporated, P.O. Box 64394, St. Paul, MN 55164 or call (612) 490-2888. A new Applications Bulletin on the Model 8110 tester will be available shortly. This Applications Bulletin provides additional information on the Model 8110 along with test data.

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APPENDIX G

Description of ATI Model TDA-100
Monodispersed Aerosol Penetrometer

TDA®-100 *(Q127)*
Monodispersed Aerosol Penetrometer

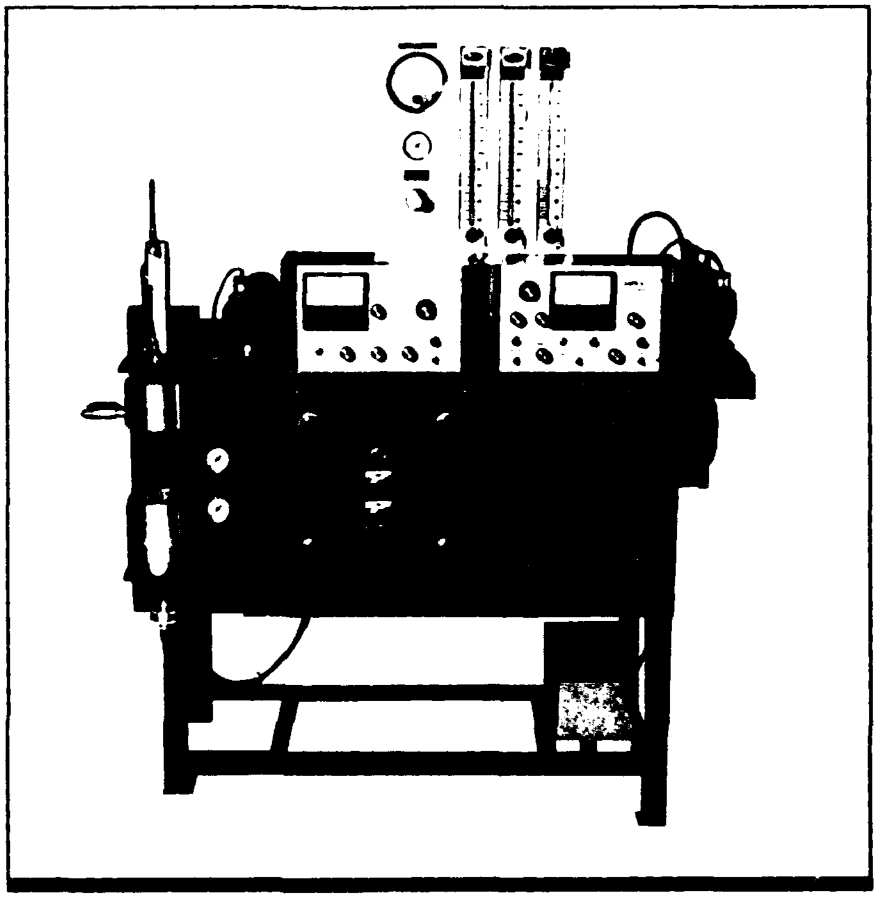
The TDA-100 Monodispersed Aerosol Penetrometer (Q127) incorporates the most advanced technology of unique design to make .3 micrometer monodispersed aerosol, measure and control the aerosol particle size and concentration plus measure the percent penetration of the tested component by the aerosol.

The TDA-100 is a basic apparatus consisting of three major components. They are:

1. The penetrometer itself consisting of the aerosol making and controlling equipment.
2. The particle size indicator and the mechanical analyzer which monitor the aerosol particle size.
3. The percent penetration indicator and associated light scattering chamber which measures the percent of aerosol penetrating the component being tested.

There are many adaptations and possibilities for various chuck and test fixtures which enable testing of a great variety of samples ranging from flat material to highly complex respirators.

In general the TDA-100 operates as follows:



Compressed air, passing through a filter and moisture trap, is connected to the penetrometer and regulated to a pressure of 35 pounds per square inch gage (psig). The air is then divided into two streams, vapor and diluent. The vapor stream flows at 20 liters per minute through a preheater, then into an aerosol generator and over the surface of liquid which is maintained at 165 ± 2°C. The diluent stream is cooled by a vortex tube and then heated by an electrical element. It bypasses the aerosol generator at a flow rate of 80 liters per minute and joins the vapor stream on the outlet side of the generator to make an aerosol. The aerosol is passed into an aging chamber where it is stabilized. During testing, aerosol flows from the aging chamber to the chuck or test fixture adaptation and through the component under test. As aerosol is continually being made when the penetrometer is operating and testing is intermittent, the excess aerosol is exhausted to the atmosphere from the aging chamber.

The aerosol particle size is maintained at a predetermined level by controls on the penetrometer and is monitored by the aerosol particle size indicator. This indicator electronically measures aerosol particle size from a sample of the aerosol continually passing through a mechanical analyzer. This mechanical analyzer measures aerosol particle size by the degree of polarization of a light beam which passes through a sample of the aerosol. The particle size of the aerosol is controlled by adjusting the temperature of the diluent air stream.

A sample under test is subject to a concentration of aerosol of approximately 100 micrograms per liter. Using this concentration as a base line of 100%, the amount of aerosol penetrating the sample under test is measured by the percent penetration indicator. Such measurements are registered linearly on the meter.

APPENDIX G

AIR TECHNIQUES
Division of Hamilton Assoc. Inc
11403 Cronridge Drive
Owings Mills, MD 21117-2247 USA
Tel 410 363 9696
Fax 410 363 9695

TDA®-100 Monodispersed Aerosol Penetrometer (Q127)

MAJOR COMPONENTS AND SPECIFICATIONS

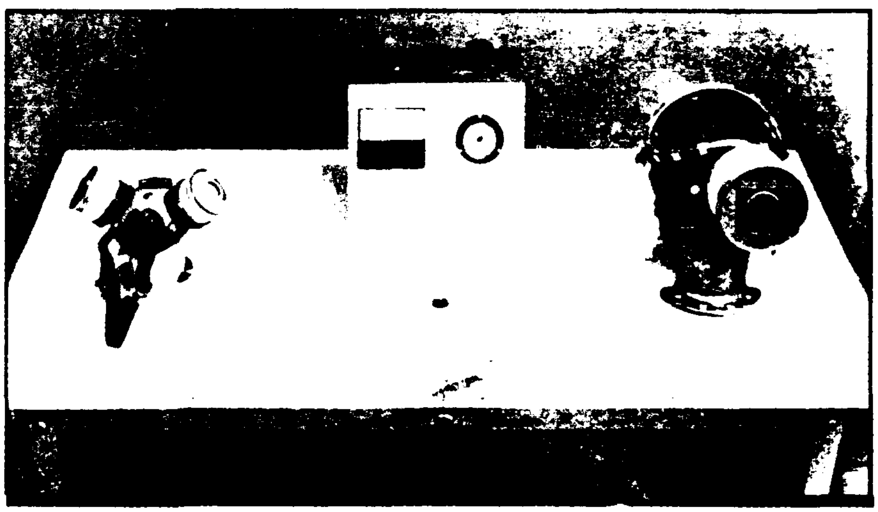
- AEROSOL GENERATOR: Produces 0.3 micron aerosol at a concentration of 100 micrograms/liter
- VAPOR FLOWMETER: Ranges from 5-50 SLPM @ 35 PSIG
- DILUENT FLOWMETER: Ranges from 10-100 SLPM @ 35 PSIG
- TEST FLOWMETER: Ranges from 16-85 SLPM @ 5" Hg
- RESISTANCE INDICATOR: Magnehelic Gage. 0-80 MM WATER COLUMN
- MECHANICAL ANALYZER: Measures light-angle polarization from 0°-50° with four polaroid and three condensing lenses
- PARTICLE SIZE INDICATOR: Solid state type, capable sensitivity of ten divisions to 1° rotation of Mechanical Analyzer, approximate size—14" × 8" × 8"
- SCATTERING CHAMBER: Forward light scattering, approximately 5" × 5" × 20" in size, with ultra black no smoke feature
- PERCENT PENETRATION METER: Solid state type with ranges of 100%, 10%, 1% .1%, .01%. Approximate size—14" × 8" × 8". Three place digital read out optional
- VORTEX TUBE: 5 cubic feet per min. capacity
- MIXING CHAMBER: Containing baffles with ports for exhaust, sample, inlet and test sample
- VACUUM PUMP: Capable of delivering up to 85 SLPM @ 5"HG pneumatic, silent operating type
- AIR OPERATED CHUCK: Manufactured to house customers' canisters of varying sizes, etc., to be tested
- CONSTANT VOLTAGE REGULATOR: 250 VA rating. Input of 95-130 VAC output of 118 VAC ± 0.5%
- CONTROL PANEL: Consisting of master "ON-OFF" particle size control, solid state time proportioning liquid temperature control, chuck control switches

APPLICABLE STANDARDS AND SPECIFICATIONS

ASTM D 2986-71
Evaluation of Air Assay
Media by the Monodisperse
DOP (Dioctyl Phthalate)

30 CFR 11
NUREG 0041
MIL STD 282

American National Standards Institute
N101.1-1972.
ANSI/ASME N510-1980.
Institute of Environmental Sciences
IES-RP-CC-001-86



A test bench, TDA 101, is available as an accessory to the TDA-100 for testing leaks in facepieces of both full and half mask respirators. The bench has two test heads, a spray nozzle for aerosol, a penetration readout meter, valves, connectors and hardware for hook-up to the TDA-100 Monodispersed Aerosol Penetrometer.

APPENDIX G

AIR TECHNIQUES
Division of Hamilton Assoc. Inc
11403 Cronridge Drive
Owings Mills, MD 21117-2247 USA
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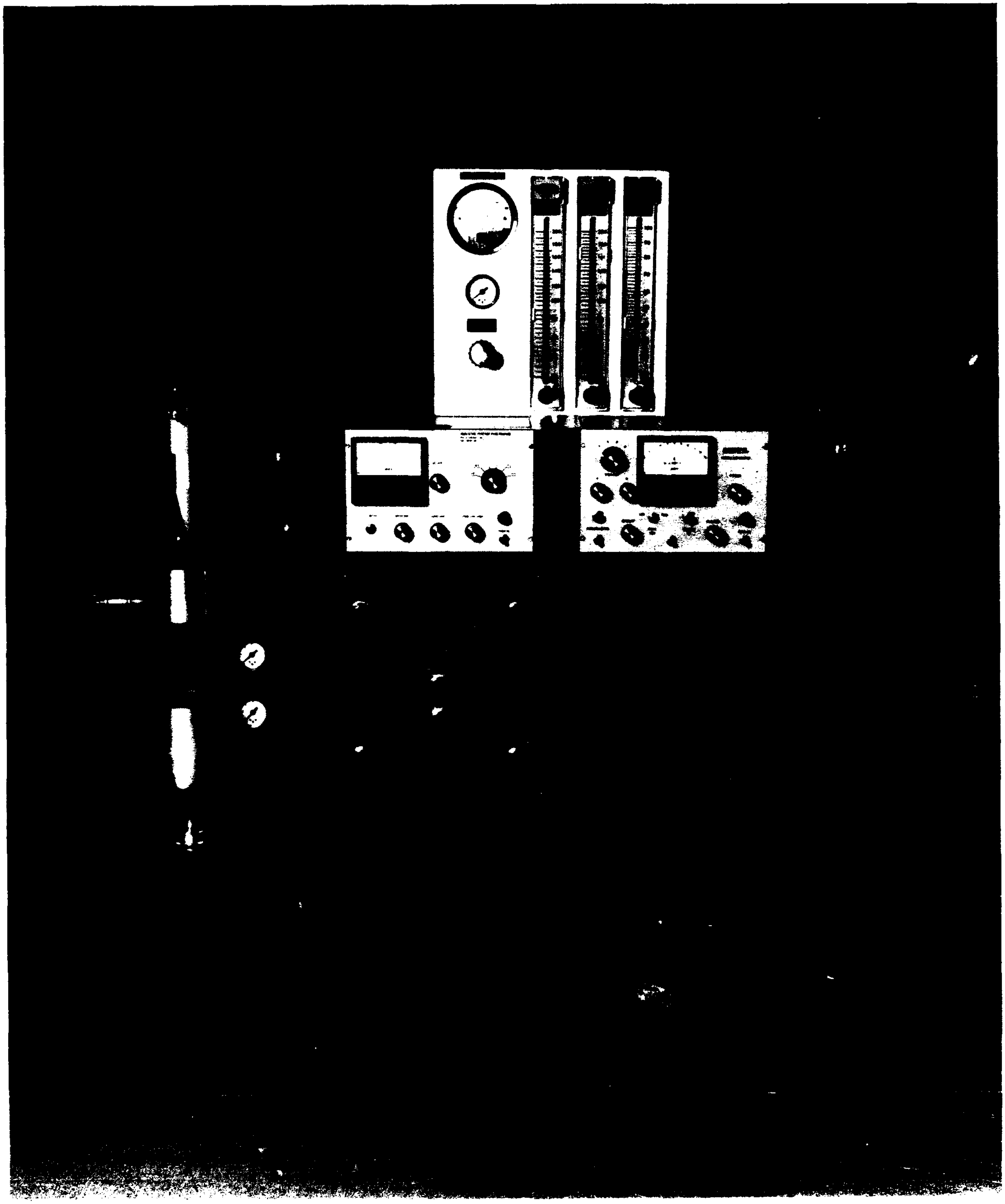
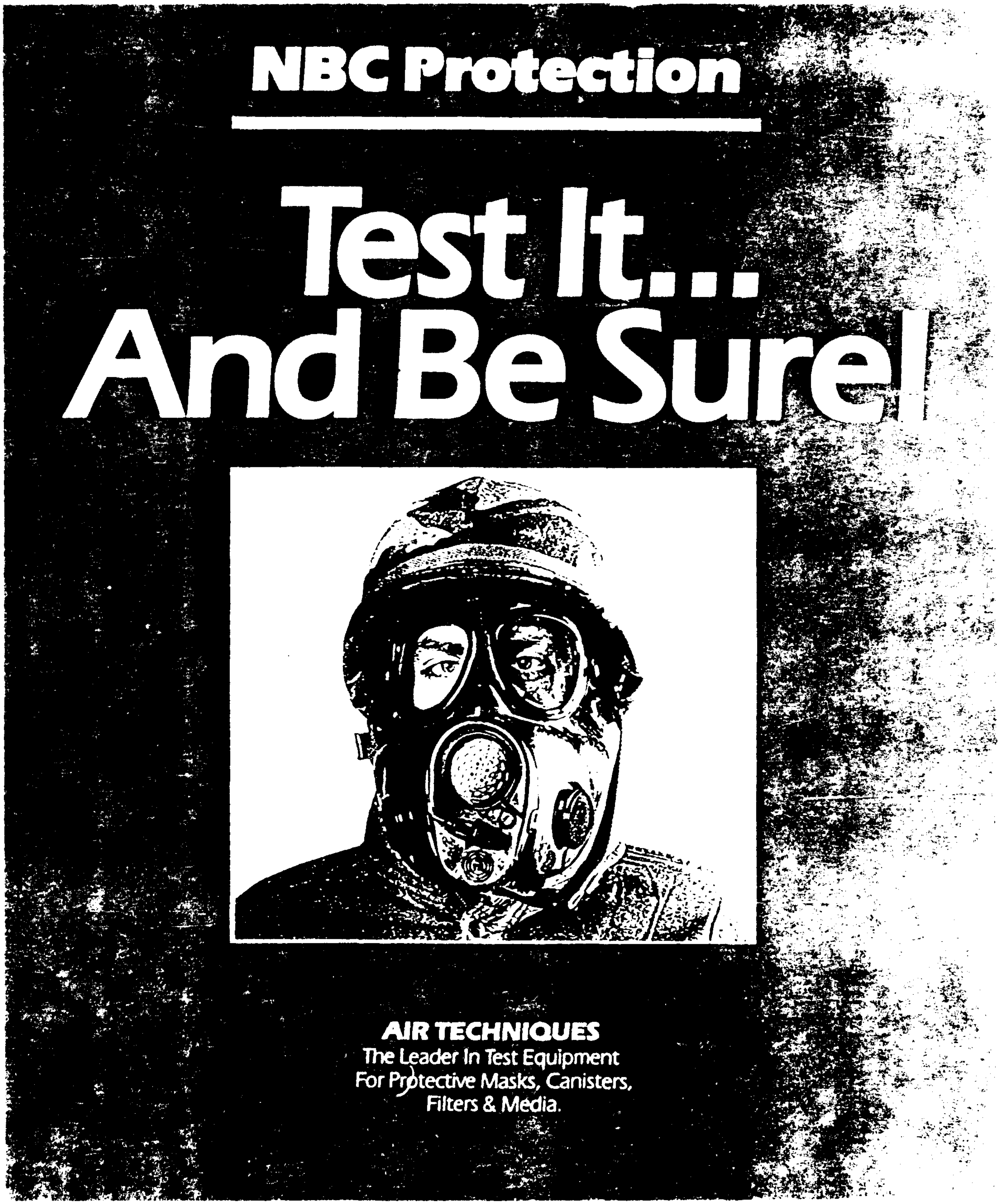
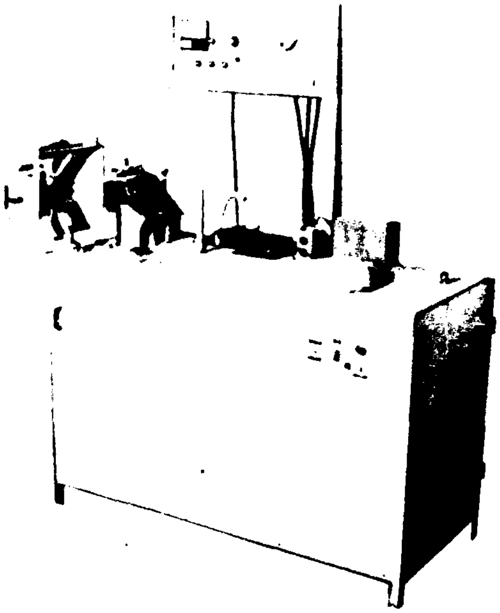
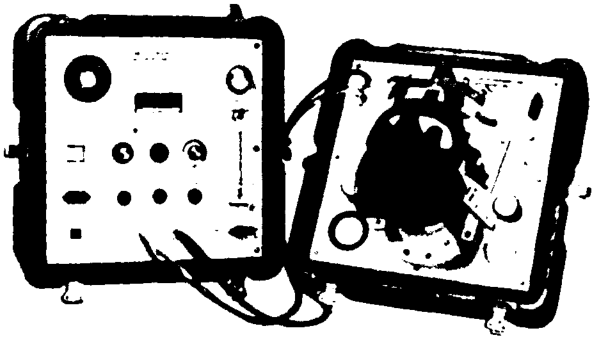


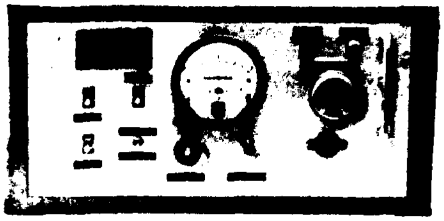

NBC Protection
Test It...
And Be Sure!
AIR TECHNIQUES
The Leader In Test Equipment
For Protective Masks, Canisters,
Filters & Media.



1
M14 Gas Mask Leakage Tester

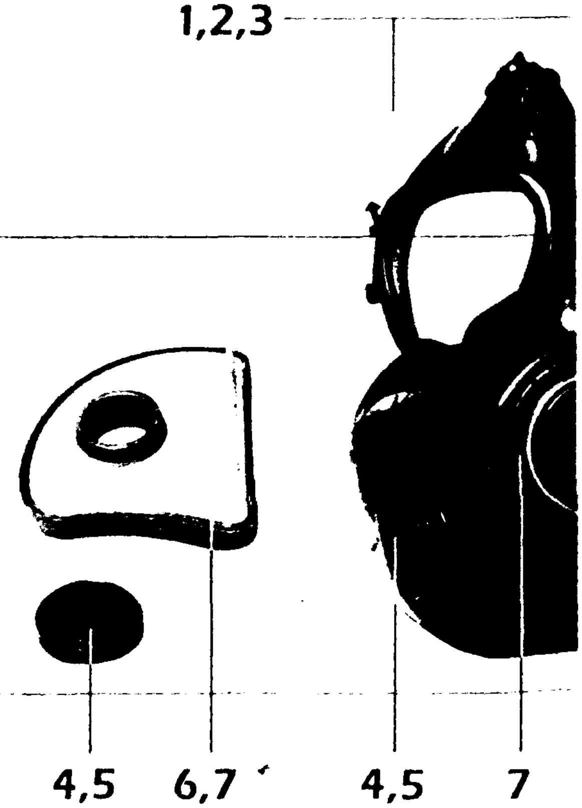
This stationary unit is built to U.S. military specifications and comprehensively tests protective masks for serviceability using an aerosol challenge. "Percent penetration" is measured by detecting the aerosol within a constant airflow. Protective masks of different types and sizes and their components can be tested by using appropriate test heads and accessories.

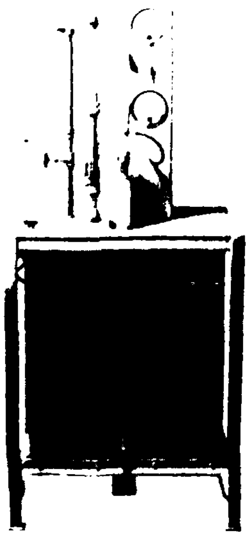




4
TDA-124 Valve Leakage Tester (M4A1)

This unit can test mask and canister valves for leakage. It has upgraded solid state design features compared to the M4A1 model. The new digital display is used to set the acceptable leakage limit and to display the actual test leakage value for SPC Statistical Process Control purposes. In addition, an Accept signal or Reject alarm confirms each test result to the operator.





6
Q112 Canister Airflow Resistance Tester

This unit measures the resistance of gas mask filters, flat sheet filter media and canisters at various airflow rates. This device can test canisters or filters for their ability to "breathe" within a required range.

NBC Test Equ

The test equipment shown here represents just a few of the many types available from Air Techniques, which assure the highest level of protection for military and civilian personnel. Some of our other units are listed on the back page.

2

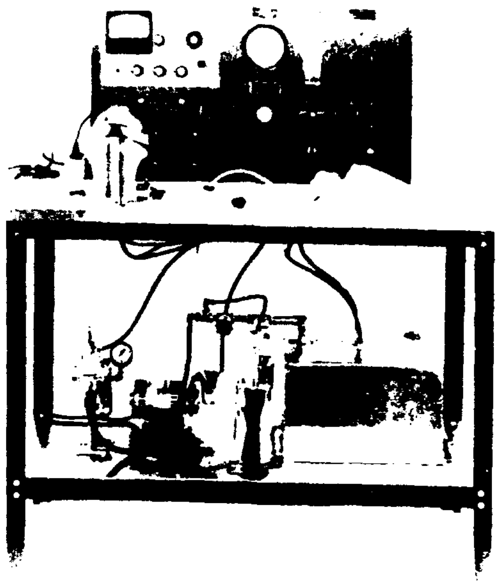
TDA-99 Gas Mask Leakage Tester (Field)

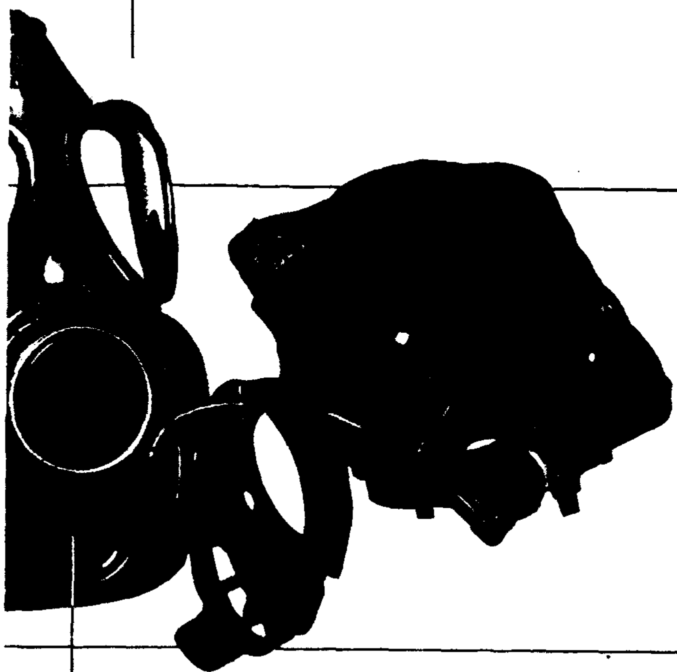
This portable unit will test the integrity of any military protective mask now in service or about to be issued. The unit has a sensitivity of 0.001% to the test agent aerosol and will detect leaks in lens assemblies, inhalation and exhalation valves, drinking tube and microphone assemblies and the facepiece itself. A complete integrity test of the mask and components can be accomplished in 1 to 2 minutes. The unit is comprised of 2 rugged self-contained modules which set up quickly in field conditions.

3

TDA-104 Gas Mask Leakage Tester

This unit is a commercial version of the M14 military model. Producers of gas masks, and the military use it to perform all the tests and procedures of the M14 model. This redesigned unit eliminates the heavy protective cabinet required in the original military design, therefore; it is less expensive and can be shipped in much less time.



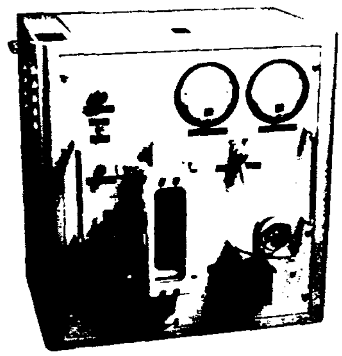


4

5

Q212 Valve Resistance Tester

This compact unit measures the resistance of various inhalation, exhalation and nose cup valves to specified air flows. Unit is adjustable to meet airflow or resistance specifications and can be provided with appropriate valve adapters.



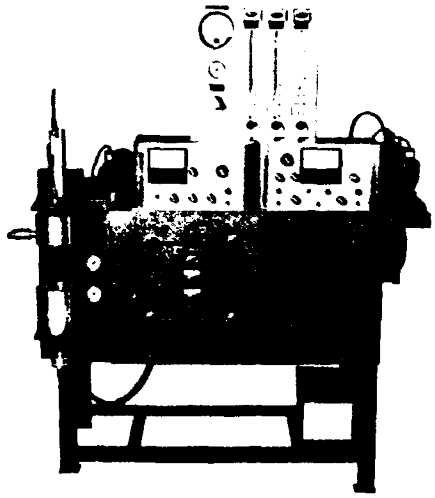
:quipment

These units are used extensively by the military, government agencies, suppliers and laboratories worldwide to evaluate the design, quality, application and performance of gas masks, components, filters and systems.

7

Q127 Filter Penetration Tester (TDA-100)

This unit generates and utilizes uniform monodispersed aerosol particles (0.3 microns) to test penetration of virtually any canister, filter, cartridge or filter media. Particle size is controlled and measured as well as the concentration. Using electronic particle size analysis and forward light scattering technology, the percent penetration is shown at selected airflows from 16 to 85 l.p.m.



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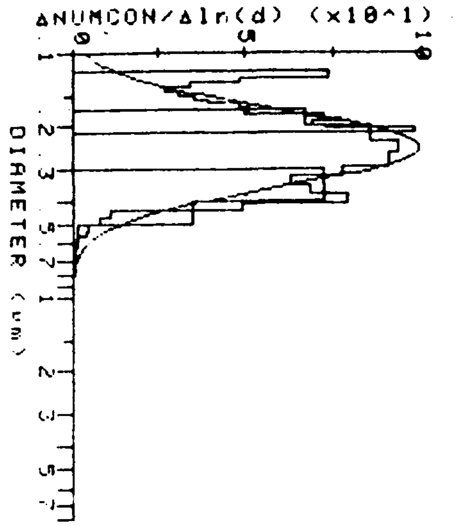
APPENDIX H

Testing with Product Assurance Directorate (PAD)



DATE 90/5/22 TIME 103920 PSLF
MAX CNTS/SEC= 458 SEC= 20
R 0-3 TRUN 0 BINS 5.00 ML/SEC
DILUTION RATIO = 1.000E+000
TEMPERATURE (C)= 2.200E+001
ATM PRESSURE (mm Hg)= 7.600E+002
REL HUMIDITY (%)= 5.000E+001
A PARAMETER = 0.000E+000
B PARAMETER = 0.000E+000
C PARAMETER = 0.000E+000
NUM CONC (NUMB/cm3)= 8.960E+001
GEOM MEAN DIAM (μm)= 2.459E-001
GEOM STANDARD DEV = 1.433E+000
MASS CONC (mg/m3)= 1.219E-003
UNDIL MASSCON(mg/m3)= 1.219E-003
MAX CNTS/SEC = 4.580E+002
PEAK DIAMETER (μm) = 2.070E-001
FIT NUM CONC (#/cm3)= 0.000E+000
FIT GEOM MN DIA (μm)= 1.000E-008
FIT GEOM STAND DEV = 1.000E+002
FIT UNDIL M0 (mg/m3)= 0.000E+000

PROBE RANGE=3 TOT CNTS= 9160

BIN	DIA	COUNT	DISTN VALUE
0	120	359	7 36E+001
1	126	228	4 90E+001
2	132	152	3 42E+001
3	138	116	2 73E+001
4	144	126	3 09E+001
5	150	140	3 57E+001
6	156	149	3 95E+001
[illegible]	162	[illegible]	4 84E+001
[illegible]	[illegible]	[illegible]	5 10E+001
[illegible]	174	[illegible]	5 01E+001
[illegible]	180	[illegible]	[illegible]
[illegible]	186	[illegible]4	7 69E+001
[illegible]	192	[illegible]	6 92E+001
[illegible]	198	218	7 30E+001
14	204	214	9 80E+001
	210 (	6163=OVERCOUNT)	

PROBE RANGE=2 TOT CNTS= [illegible]

BIN	DIA	COUNT	DISTN VALUE
0	.170	1090	6 71E+001
1	.200	1157	[illegible] 56E+001
2	.230	1139	9 29E+001
3	.260	990	9 07E+001
4	.290	760	7.72E+001
5	.320	566	6 32E+001
6	.350	560	6.81E+001
7	.380	601	7.91E+001
8	.410	350	4.96E+001
9	.440	76	1 15E+001
10	.470	50	8.08E+000
11	.500	30	5.15E+000
12	.530	22	4 00E+000
13	.560	10	1.92E+000
14	.590	7	1 41E+000
	.620 (	20=OVERCOUNT)	

PROBE RANGE=1 TOT CNTS= 2932

BIN	DIA	COUNT	DISTN VALUE
0	.300	2081	7.23E+001
1	.400	783	3.51E+001
2	500	35	1.92E+000
3	.600	19	1.23E+000
4	.700	11	8.24E-001
5	.800	0	0.00E+000
6	.900	0	0.00E+000
7	1.000	2	2.10E-001
8	1.100	0	0.00E+000
9	1.200	0	0.00E+000
10	1.300	0	0.00E+000
11	1.400	1	1.45E-001
12	1.500	0	0.00E+000
13	1.600	0	0.00E+000
14	1.700	0	0.00E+000
	1.800 (	0=OVERCOUNT)	

PROBE RANGE=0 TOT CNTS= 0

BIN	DIA	COUNT	DISTN VALUE
0	1 500	0	0 00E+000
1	1 900	0	0.00E+000
2	2 300	0	0 00E+000
3	2 700	0	0.00E+000
4	3.100	0	0 00E+000
5	3.500	0	0.00E+000
6	3 900	0	0 00E+000
7	4 300	0	0 00E+000
8	4.700	0	0.00E+000
9	5 100	0	0 00E+000
10	5 500	0	0 00E+000
11	5.900	0	0 00E+000
12	6.300	0	0.00E+000
13	6 700	0	0 00E+000
14	7.100	0	0 00E+000
	7 500 (	0=OVERCOUNT)	

Machine: Q 233
Geometric Mean Diameter (GMD): 0 2459 μm
Geometric Standard Deviation (GSD) 1.433
"Hot Pot" Temperature: 195 °C
Particle Size Control Setting: 75 volts
Owl Reading: 29 degrees
Total Flow: 118 scfm

Table. Performance of DOP in the PAD Q 233 Machine

Main Flow Schematic Key

1 - Variable speed blower

2 - Generator diverting valve

3 - Diluent flow control valve

4 - Diluent orifice & Magnehelic gage

5 - Diluent heater 500 watts

6 - Vapor flow control valve

7 - Vapor orifice & Photohelic gage

8 - Vapor air heater 1000 watts

9 - DOP generator

10 - Mixing chamber

11 - Exhaust damper & controller

12 - Purgeflow valve electrically actuated

13 - 20% flow control valve remotely operated

14 - 100% flow control valve remotely operated

15 - Upstream chuck plenum

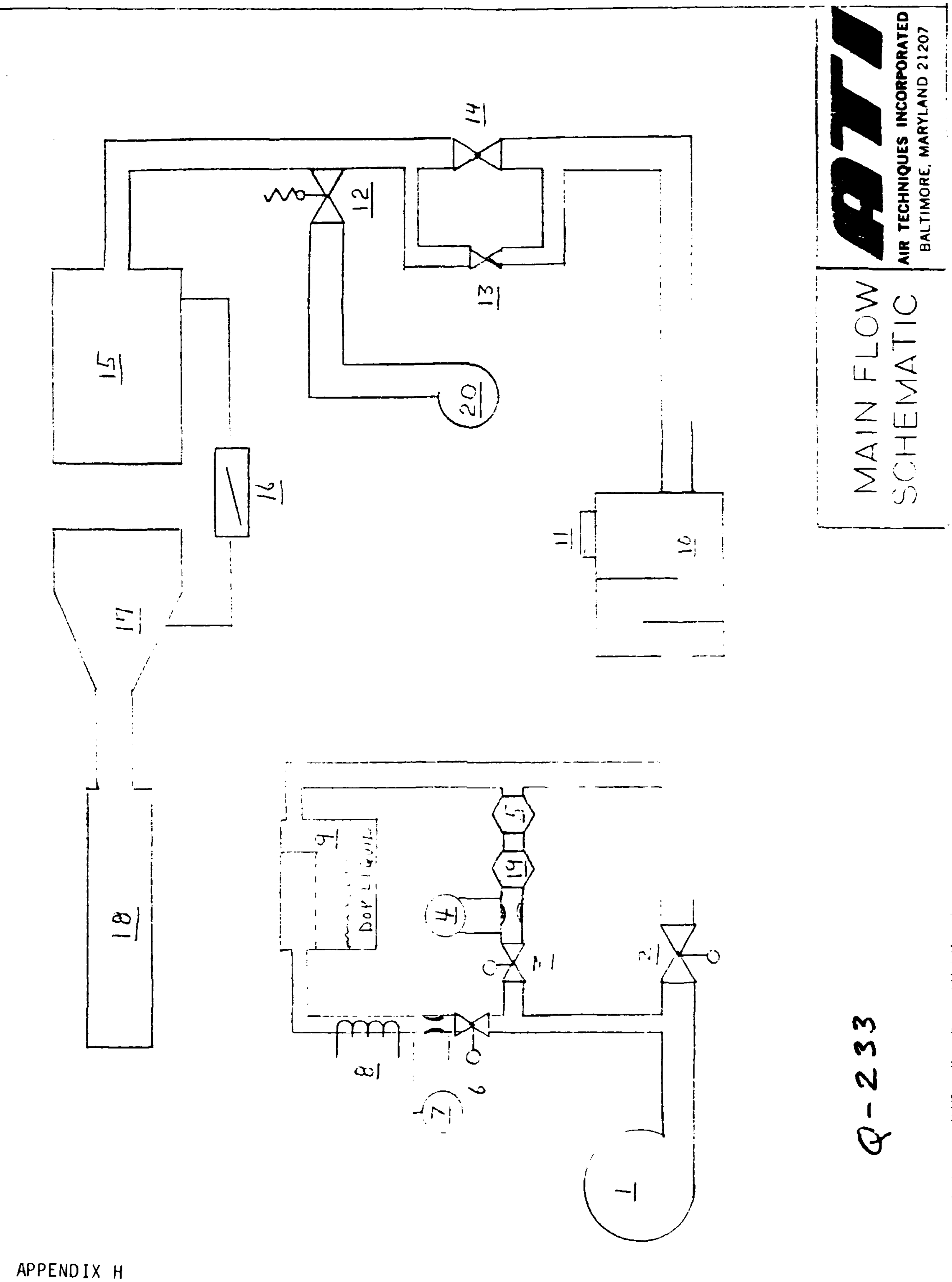
16 - Filter resistance inclined manometer

17 - Downstream chuck plenum

18 - Mass flow transducer

19 - Heat Exchanger

20 - Blower Purge Air



MAIN FLOW SCHEMATIC
AIR TECHNIQUES INCORPORATED
BALTIMORE, MARYLAND 21207
Q-233
DOP LIQUID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

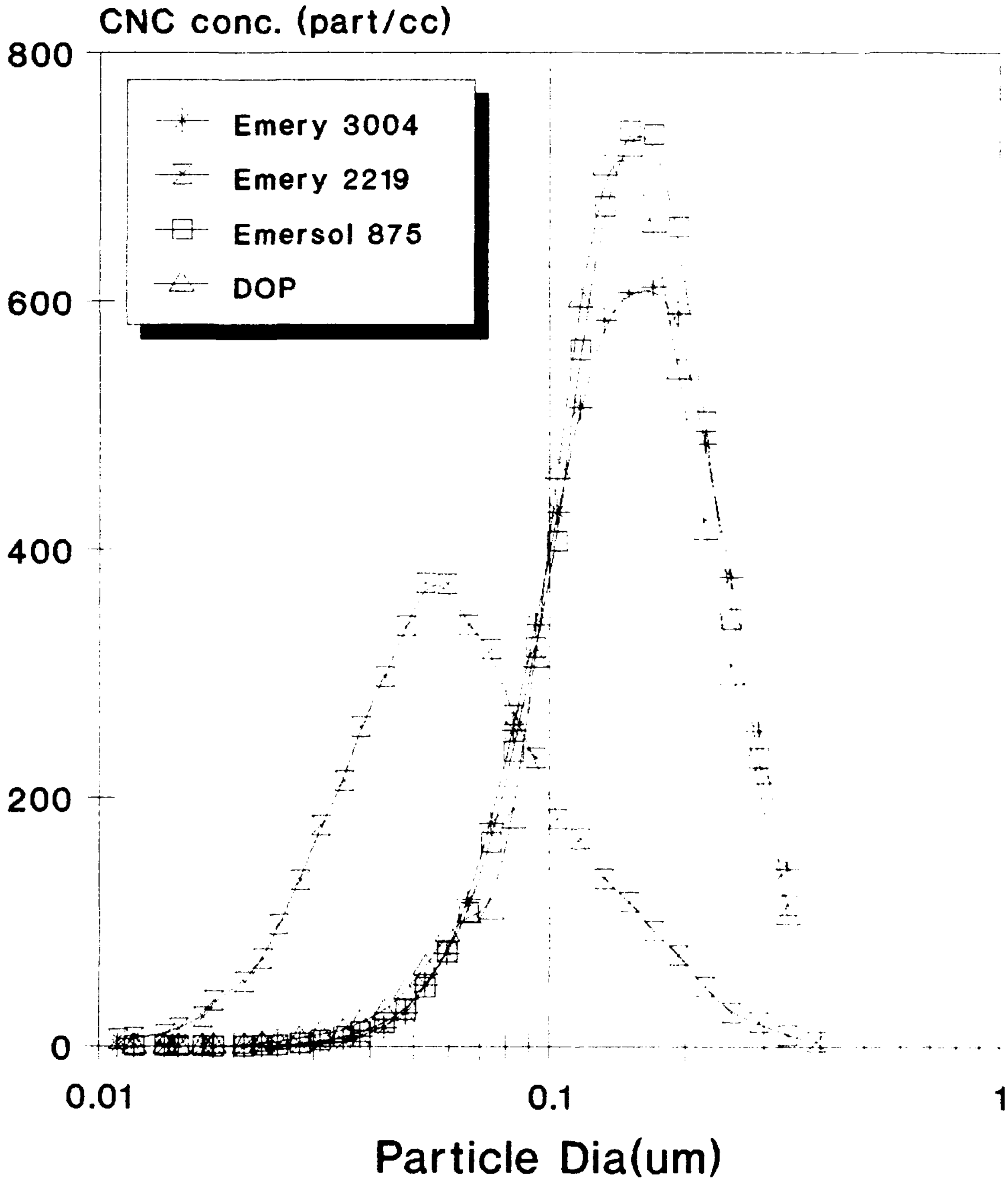
APPENDIX H

APPENDIX I

Testing with the National Institute For Occupational Safety and Health (NIOSH)

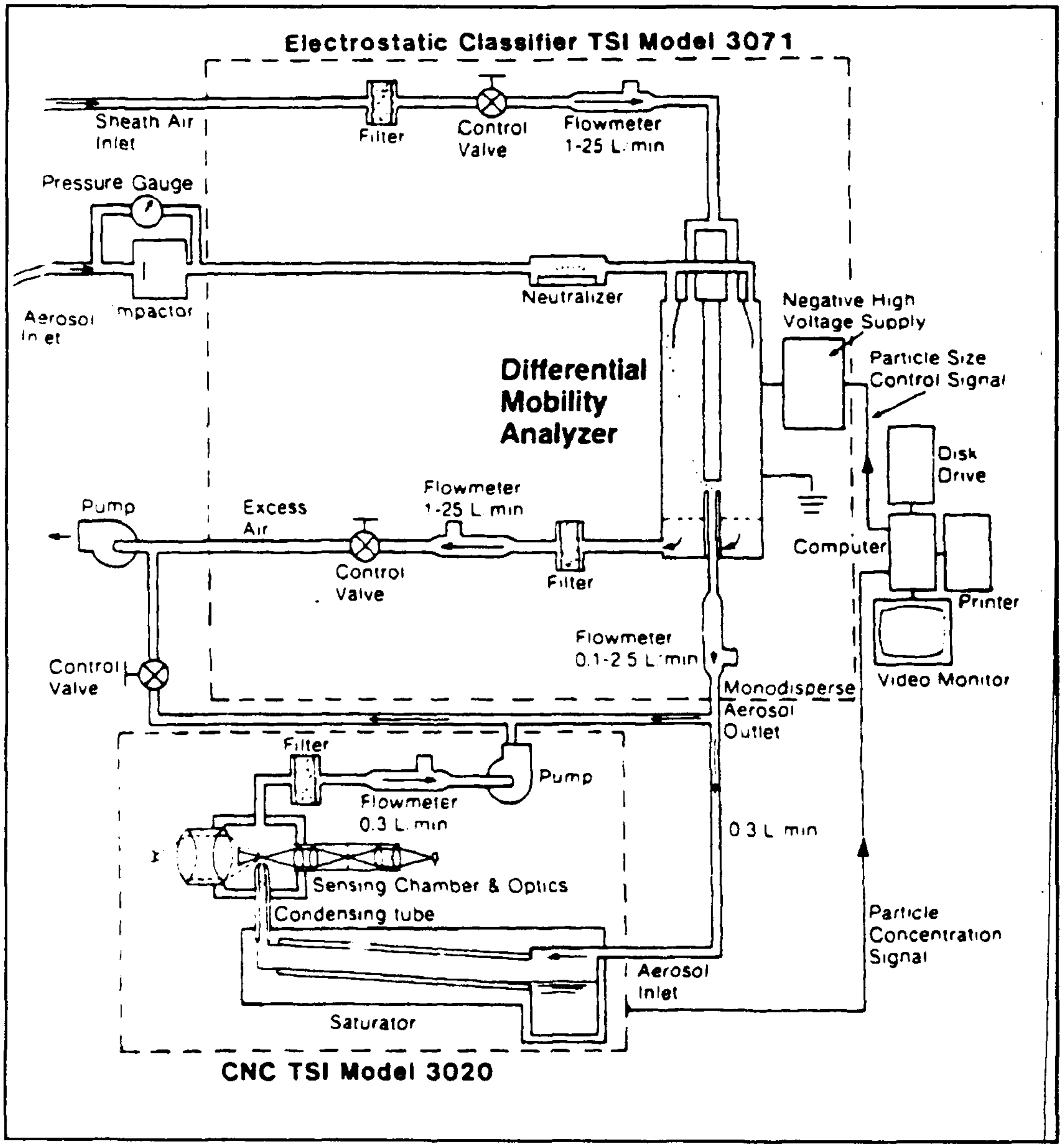
Table. Mean values of Aerosols generated in the 8110 using candidate materials, in high and low concentration modes.

Material /Mode	Number Dia.	Spread	Surface Dia.	Spread	Volume Dia.	Spread
DOP						
High	0.138	1.528	0.184	1.400	0.203	1.353
Low	0.118	1.705	0.181	1.478	0.206	1.390
Emersol 875						
High	0.164	1.512	0.208	1.332	0.223	1.282
High	0.158	1.524	0.203	1.345	0.219	1.296
Low	0.139	1.734	0.201	1.388	0.220	1.313
Low	0.138	1.746	0.200	1.392	0.219	1.316
Emery 3004						
Low	0.123	1.771	0.192	1.457	0.215	1.357
Low	0.122	1.804	0.194	1.454	0.217	1.349
High	0.158	1.534	0.206	1.356	0.223	1.298
High	0.157	1.53	0.205	1.360	0.222	1.302
Emery 2219						
Low	0.054	1.969	0.142	1.838	0.188	1.560
Low	0.052	2.09	0.15	1.828	0.195	1.524
High	0.051	1.853	0.117	1.864	0.162	1.673
High	0.051	1.866	0.115	1.851	0.159	1.668



CNC conc. (part/cc)
800
600
400
200
0
Emery 3004
Emery 2219
Emersol 875
DOP
0.01
0.1
1
Particle Dia(um)

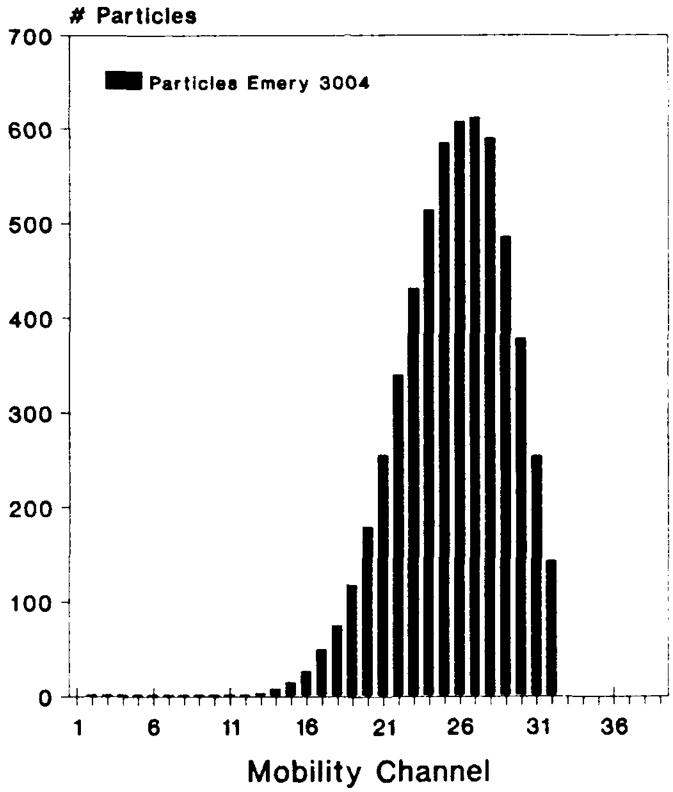
Figure. Schematic view of the DMPS with Electrostatic Classifier(EC) and Condensation Nucleus Counter(CNC). Particles entering the classifier are neutralized prior to being recharged and separated according to their electrostatic mobility. The CNC counts the number of particles in each mobility channel. Data is collected on a microcomputer.



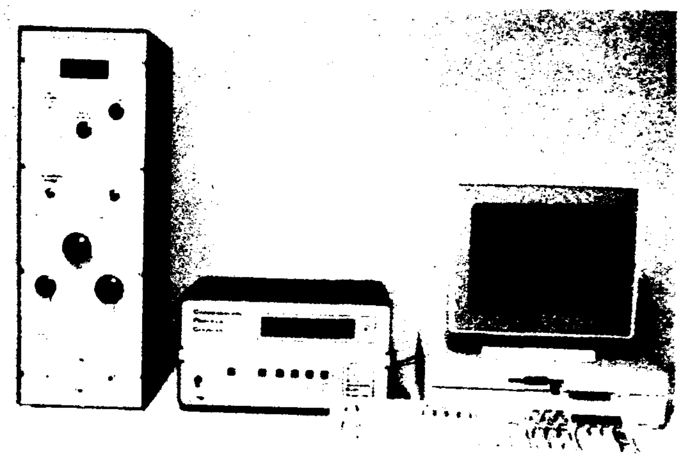
Mass concentrations were calculated for each candidate material in both high and low concentration modes.

DOP	High mode	110.0 ug/L	Low mode	10.0 ug/L
Emersol 875	High mode	114.9 ug/L	Low mode	12.9 ug/L
Emery 3004	High mode	167.0 ug/L	Low mode	16.0 ug/L
Emery 2219	High mode	145.0 ug/L	Low mode	2.0 ug/L

The TSI DMPS prints a chart of particle distribution as particles per mobility channel. Figure is an example of a printout of particle distribution per mobility channel generated with Emery 3004.

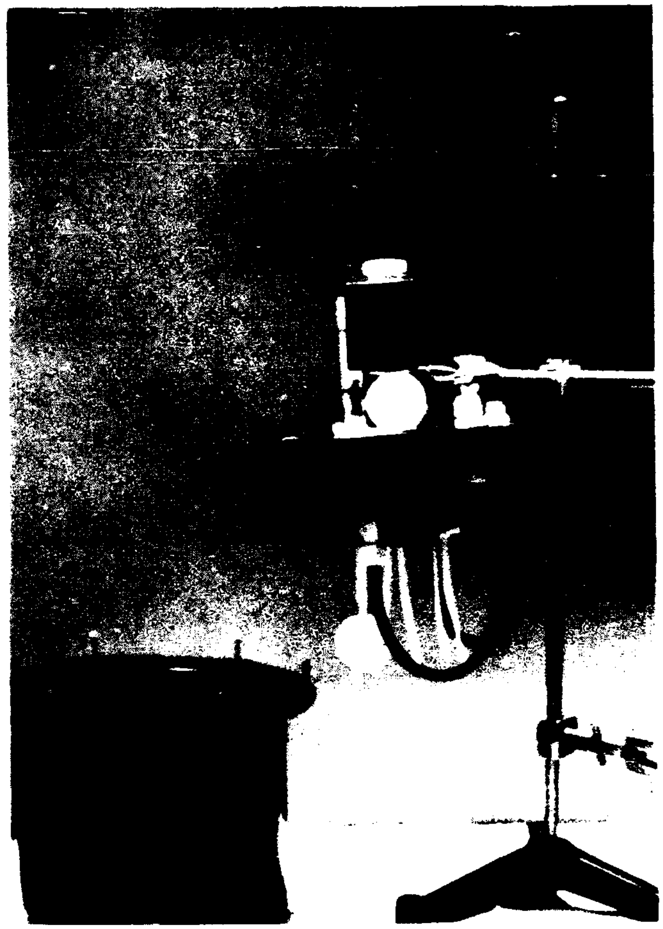


TSI, Inc., DMPS System (Model 3932)



The Model 3932 Differential Mobility Particle Sizing System offers superb resolution in a moderate sampling time for reliable measurement of stable aerosols with submicrometer particles. Because it resolves sizes over a total of 32 channels spanning the 0.01 to 1.0 μm range, it allows the operator to observe very slight differences in particle size. The DMPS offers the unique flexibility of components which, aside from working as integral parts of the system, operate as stand-alone instruments.

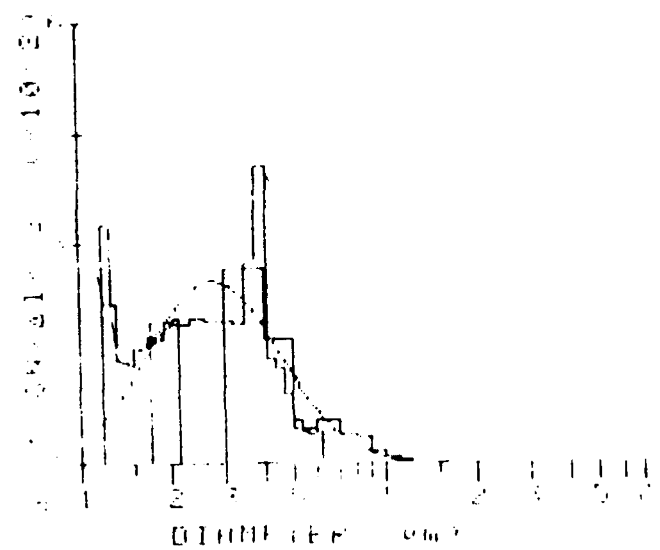
Model 8110 Smoke Generator:



Corn Oil Droplet Distribution from Model 8110 in NIOSH Tests:

Geometric Mean Diameter= 0.2744 um (GMD)

Geometric Standard Deviation= 1.647 (GSD)



APPENDIX J

Consultative Assistance to Los Alamos National Laboratory (LANL)

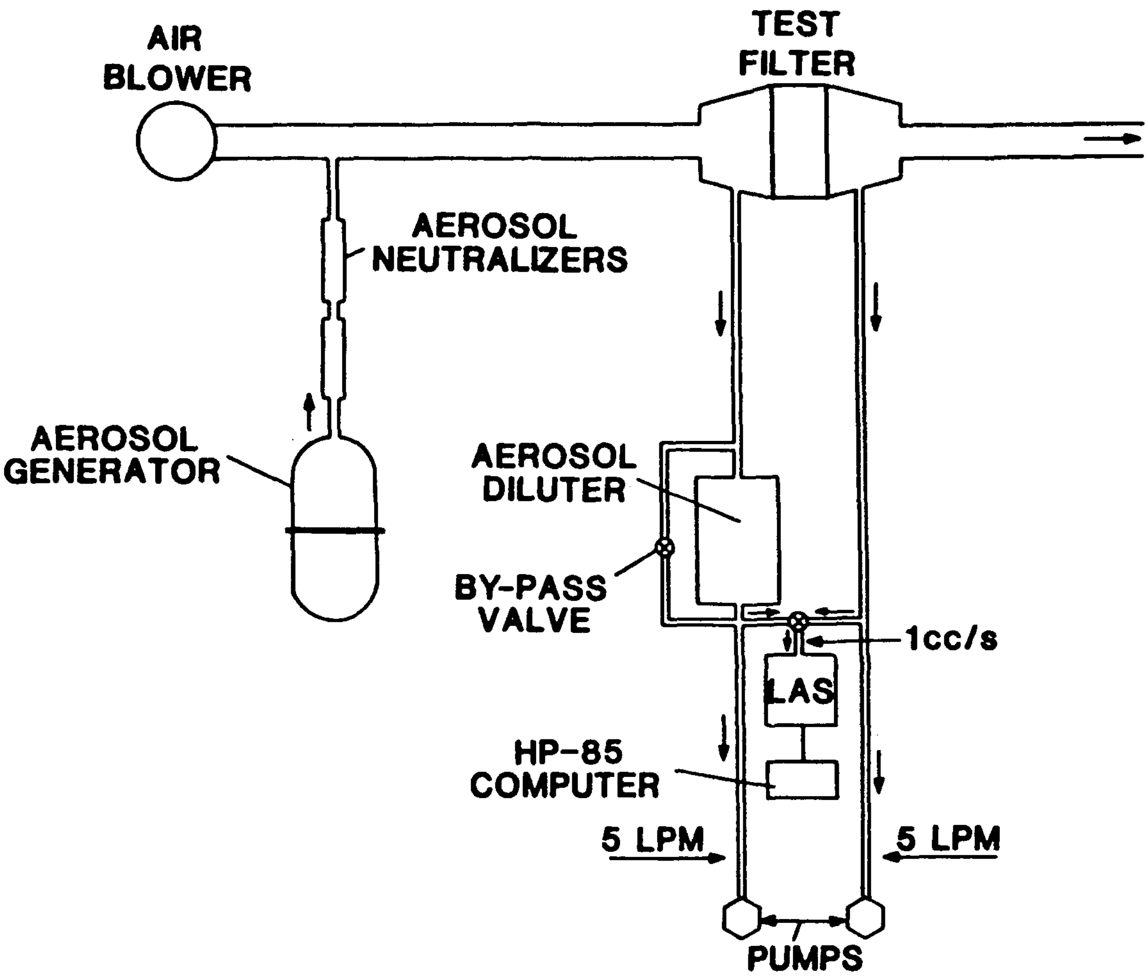


Fig. J-1. A schematic diagram of the ATS showing the major components of the system, which includes the aerosol generator, the aerosol neutralizers, the ATS aerosol diluter, the laser aerosol spectrometer, and the HP-85 computer.

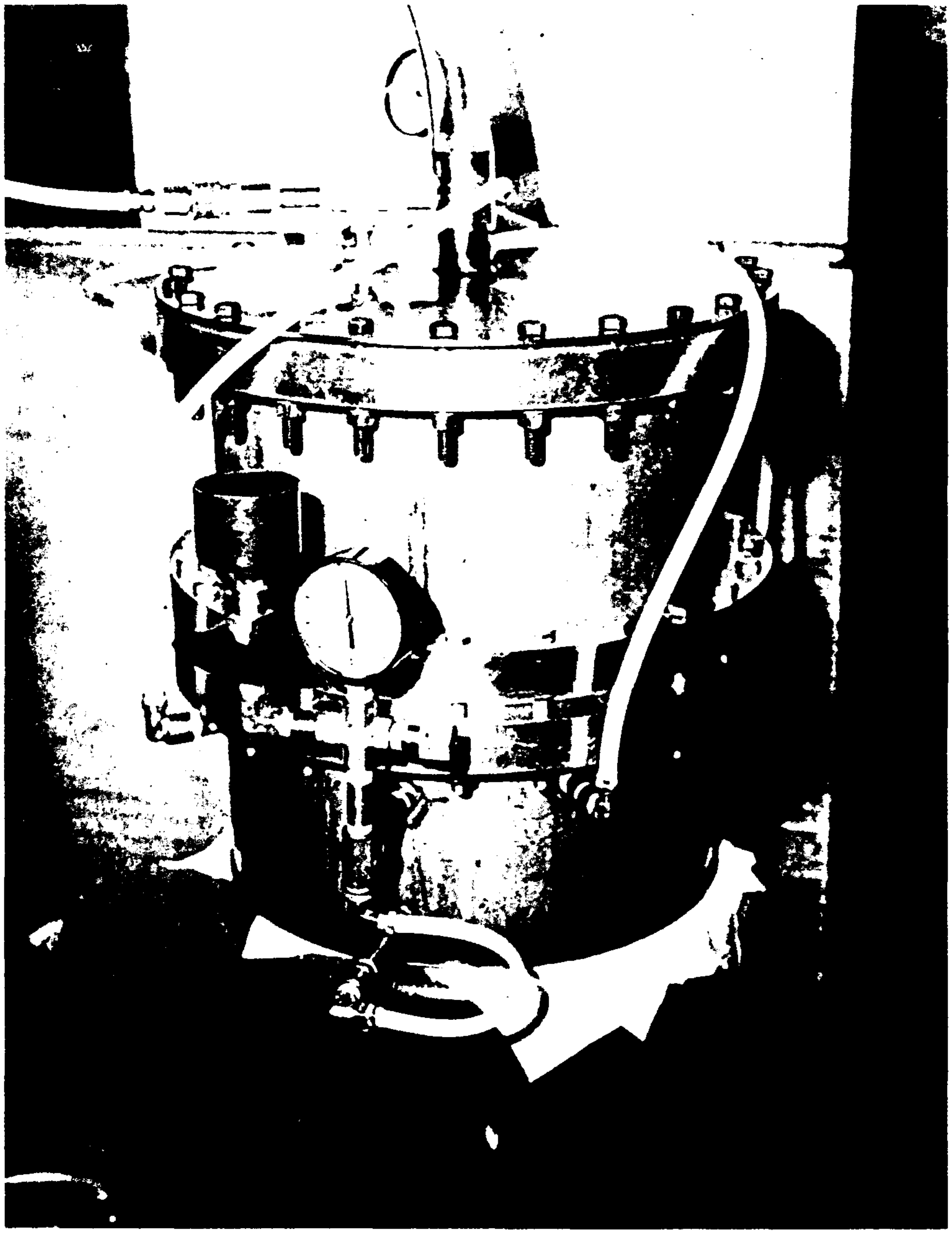


Fig. J-2. The prototype aerosol generator.

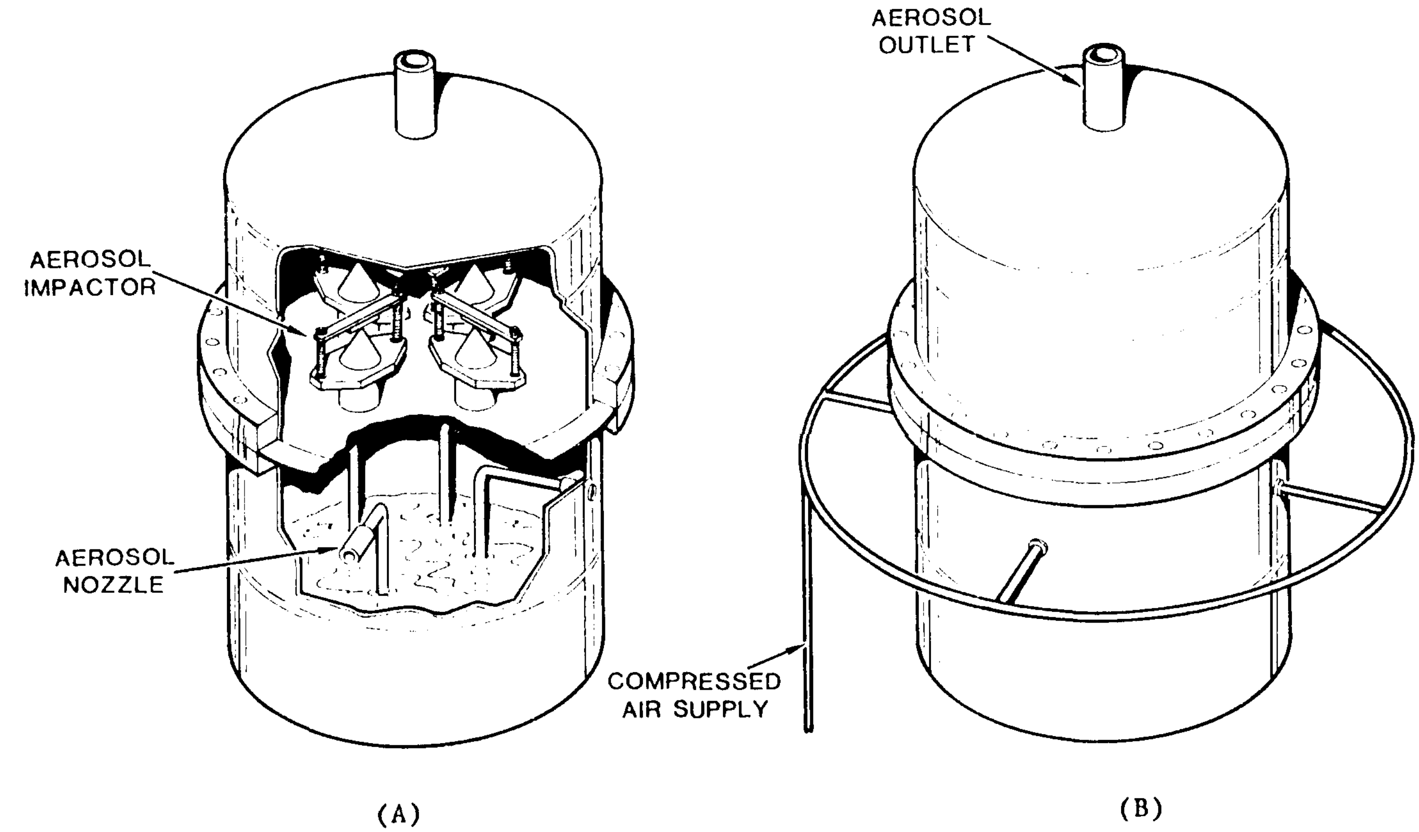
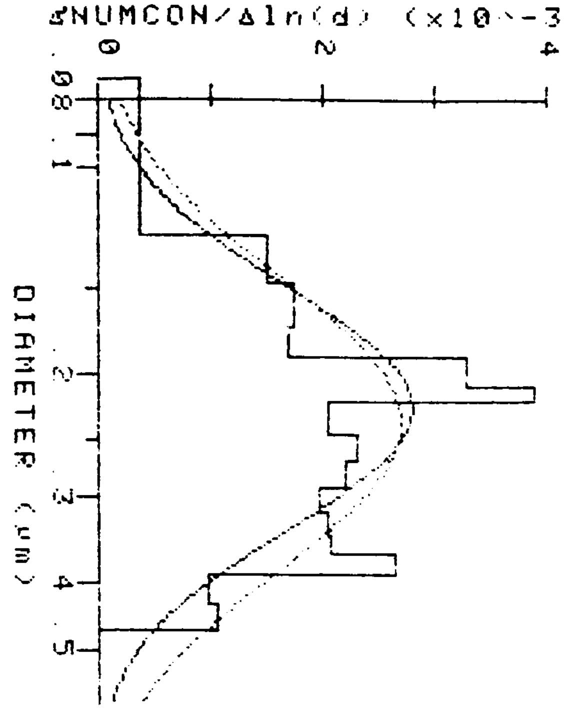


Fig. J -3. A diagram with two views of the ATS aerosol generator. View A shows the internal components of the generator and View B shows the compressed-air manifold.



DATE 90/10/24 TIME 141720 DEHP
1.00 (mL/SEC) 100010 SEC
DILUTION RATIO = 1.000E+000
DIL TOT FLOW (L/min)= 0.000E+000
DIL ORIF ΔP (IN H20)= 0.000E+000
OWL POL ANGLE (DEG)= 0.000E+000
TEMPERATURE (C)= 0.000E+000
ATM PRESSURE (mm Hg)= 0.000E+000
REL HUMIDITY (%)= 0.000E+000
NUM CONC (NUMB/cm3)= 2.810E-003
GEOM MEAN DIAM (μm)= 2.237E-001
GEOM STANDARD DEV = 1.491E+000
MASS CONC (mg/m3)= 2.999E-008
UNDIL MASSCON(mg/m3)= 2.999E-008
MAX CNTS/SEC = 2.810E-003
PEAK DIAMETER (μm) = 2.144E-001
FIT NUM CONC (#/cm3)= 3.248E-003
FIT GEOM MN DIA (μm)= 2.355E-001
FIT GEOM STAND DEV = 1.614E+000
FIT UNDIL M0 (mg/m3)= 6.230E-008

BIN	DIA	COUNT	DISTN VALUE
0	.075	20	3.65E-004
1	.126	24	1.49E-003
2	.148	25	1.73E-003
3	.171	17	1.70E-003
4	.189	33	3.28E-003
5	.209	20	3.90E-003
6	.220	22	2.04E-003
7	.245	20	2.33E-003
8	.267	19	2.21E-003
9	.291	17	1.99E-003
10	.317	15	2.06E-003
11	.341	13	2.08E-003
12	.363	17	2.66E-003
13	.387	10	9.70E-004
14	.429	9	1.06E-003
	.467		7=OVERCOUNT

Material: Emersol 875 Isostearic Acid

Flow: 300 CFM

Pressure: 25 PSI

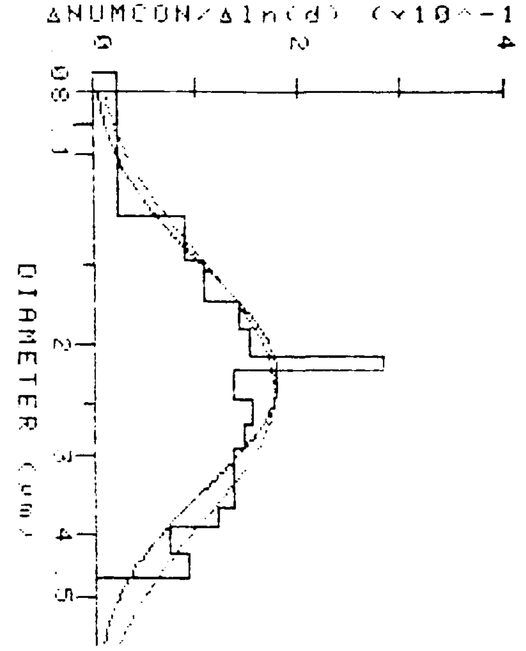
Generator(s): One

Fig. J-4. HFATS Data (See Report Section 2.3.2.1)

APPENDIX J

CURRENT OPTIONS:
PENBIN IS # 9
DILRAT FOR PENBIN IS 248.4
PRINT PENBIN PENETRATION ONLY.

100%
UPSTREAM: 1887 CNTS/SEC



DATE 90/10/23 TIME 82636 DEHP
1.00 (mL/SEC) 100010 SEC

DILUTION RATIO =	1.000E+000
DIL TOT FLOW (L/min)=	0.000E+000
DIL ORIF ΔP (IN H20)=	0.000E+000
OWL POL ANGLE (DEG)=	0.000E+000
TEMPERATURE (C)=	0.000E+000
ATM PRESSURE (mm Hg)=	0.000E+000
REL HUMIDITY (%)=	0.000E+000
NUM CONC (NUMB/cm3)=	1.813E-001
GEOM MEAN DIAM (um)=	2.264E-001
GEOM STANDARD DEV =	1.493E+000
MASS CONC (mg/m3)=	2.014E-006
UNDIL MASSCON(mg/m3)=	2.014E-006
MAX CNTS/SEC =	1.813E-001
PEAK DIAMETER (um) =	2.144E-001
FIT NUM CONC (#/cm3)=	2.093E-001
FIT GEOM MN DIA (um)=	2.366E-001
FIT GEOM STAND DEV =	1.602E+000
FIT UNDIL M0 (mg/m3)=	3.946E-006

BIN	DIA	COUNT	DISTN VALUE
0	.075	1243	2.40E-002
1	.126	1461	9.08E-002
2	.148	1551	1.07E-001
3	.171	1436	1.43E-001
4	.189	1527	1.52E-001
5	.209	1452	2.83E-001
6	.220	1471	1.37E-001
7	.245	1346	1.57E-001
8	.267	1276	1.46E-001
9	.291	1172	1.37E-001
10	.317	1005	1.38E-001
11	.341	862	1.36E-001
12	.363	784	1.33E-001

Material: Emery 3004

Flow: 1500 CFM

Pressure: 15 PSI

Generator(s): Two

Fig. J-5. HEATS Data (See Report Section 3.2.1)

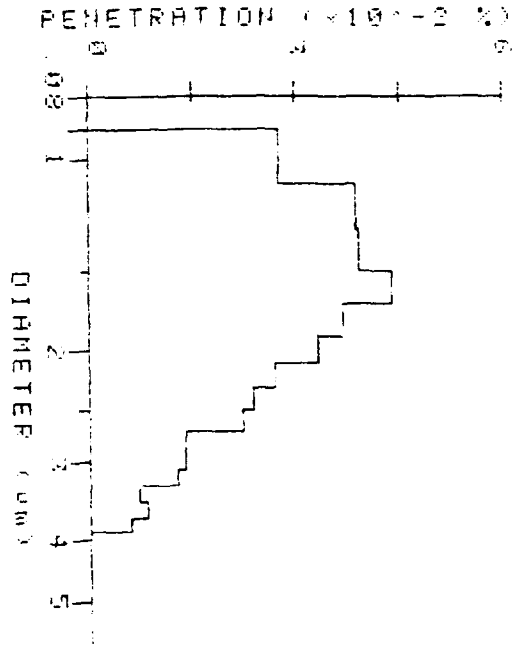
CURRENT OPTIONS:
PENBIN IS # 9
DILUTION RATIOS ARE:

BIN #	0	1	2	3	4
DILRAT	248	246	235	244	245
BIN #	5	6	7	8	9
DILRAT	245	261	242	233	248
BIN #	10	11	12	13	14
DILRAT	248	240	255	248	256

PRINT ALL PENETRATION VALUES

100%
UPSTREAM: 1486 CNTS/SEC
DOWNSTREAM: 101 CNTS/SEC

FILTER ID
1500 CFM
BIN 9 PENETRATION = .013 %



Percent Penetration Data:

Material: Emery 3004

Flow: 1500 CFM

Percent of
Filter Capacity: 100%

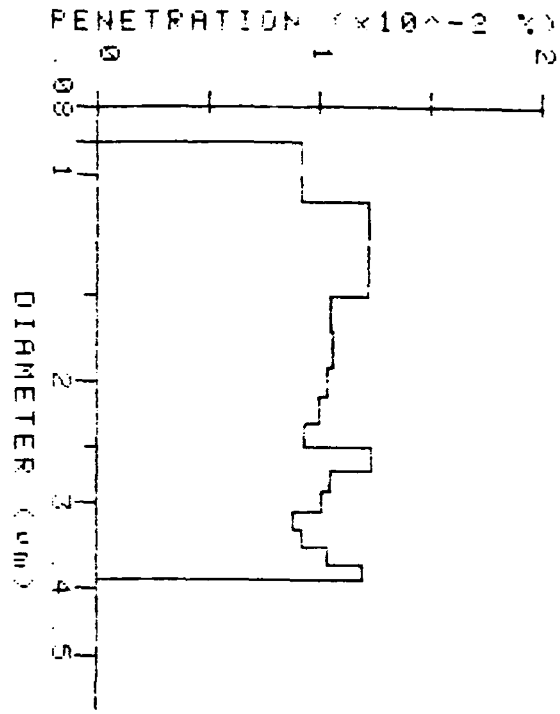
Fig. J-6. HFATS Data (See Report Section 2.3.2.1)

PENETRATION TABLE
(CALCULATED ONLY FOR BINS
WITH 10 PARTICLES OR MORE)

BIN	DIAM	PEN (%)
0	.090	2.75E-002
1	.110	3.88E-002
2	.130	3.91E-002
3	.150	4.38E-002
4	.170	3.67E-002
5	.190	3.30E-002
6	.210	2.68E-002
7	.230	2.37E-002
8	.250	2.23E-002
9	.270	1.38E-002
10	.290	1.39E-002
11	.310	1.28E-002
12	.330	7.12E-003
13	.350	6.24E-003
14	.370	6.14E-003
	.390	

20%
UPSTREAM: 1506 CNTS/SEC
DOWNSTREAM: 39 CNTS/SEC

FILTER ID:
1500 CFM
BIN 9 PENETRATION = .01 %



PENETRATION TABLE
(CALCULATED ONLY FOR BINS
WITH 10 PARTICLES OR MORE)

BIN	DIAM.	PEN (%)
0	.090	9.25E-003
1	.110	1.22E-002
2	.130	1.22E-002
3	.150	1.05E-002
4	.170	1.06E-002
5	.190	1.04E-002
6	.210	1.00E-002
7	.230	9.31E-003
8	.250	1.23E-002
9	.270	1.05E-002
10	.290	1.02E-002
11	.310	8.78E-003
12	.330	9.27E-003
13	.350	1.04E-002
14	.370	1.20E-002
	.390	

Percent Penetration Data:

Material: Emery 3004

Flow: 1500 CFM

Percent of
Filter Capacity: 20%

Fig. J-7. HFATS Data (See Report Section 2.3.2.1)

Blank

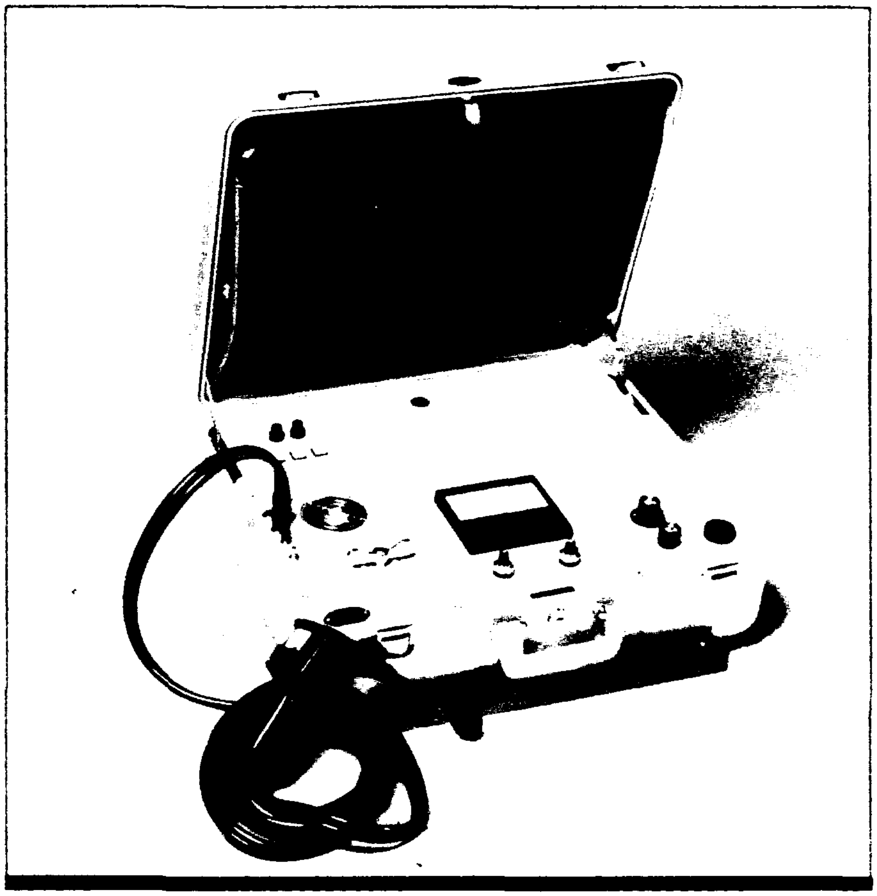
TDA®-2E Particulate Detection Apparatus

"Cold Smoke" Machines

The TDA-2E Particulate Detection Apparatus represents the latest development in forward light scattering photometry in a portable, self-contained unit. The TDA-2E has been designed with the user in mind for simplicity of operation and virtually maintenance-free use. Its basic purpose is to detect and measure mass concentration of particulate matter in air.

A stream of clean air from an internal air filter is passed through the chamber and the instrument is balanced electrically and with respect to any incidental stray light or dark current. A base line of response may be set as a basis of comparison, using the internal reference circuit, which is set for 100 micrograms of polydispersed particles, or by the user against any concentration of matter up to 1×10^{20} particles per cubic foot whose particle size may range from 0.1 micron up to 100 microns. Once the base line has been set, any subsequent readings will be in relation to that base line. The range of concentration readable is from 100 to 0.0001 on 5 linear scales on the standard instrument.

When a sample to be assessed is passed through the forward light scattering chamber, it passes through light emanating from a constant source through a lens systems. The light is reflected forward off the particles and concentrated on a phototube, and the resulting signal is fed into the amplifier circuits where it is translated into linear readings on a meter. The standard instrument is equipped with a meter, but digital readout may be added.



APPLICATIONS

Industrial, medical, pharmaceutical, nuclear, stack sampling, pollution monitoring, smoke detection, respirator and gas mask face fit tests, clean rooms, filter banks, scrubbers, powdered materials, continuous monitoring, computer contamination control, and any type of particulate monitoring or detection including Asbestos Negative Handling Machines.

SPECIFICATIONS AND FEATURES

Cabinet — Heavy duty aluminum carrying case
Size — 17" × 21" × 7½"
Weight — 35 pounds
Vacuum Pump — Continuous duty, oil-less, carbon vanes
Amplifier — Solid-state, linear readout
Scattering Chamber — Forward scattering, no moving parts, aluminum construction
Voltage Regulation — ±0.02%
Detection Sensitivity — Reads to 0.0001% linear
Handlemeter — Probe is equipped with a meter to read remotely 12 feet from unit with flexible tip
Recorder Jack — 0-1 VDC standard on all units
Adjustable audible alarm
Quartz halogen state of the art lamp
Built-in memory for 100 micrograms per liter reference

ATI

AIR TECHNIQUES
DIVISION OF HAMILTON ASSOCIATES [illegible]
[illegible] WHITEHEAD ROAD
BALTIMORE MARYLAND [illegible]
TELEPHONE [illegible] 944 [illegible]
FAX [illegible]

TDA®-2E Particulate Detection Appara...

TDA-2EL (See Note 1)
Has 5 decades of linear readout plus a direct reading logarithmic scale.

TDA-2EN (See Note 2)
Standard TDA-2E with replaceable sealed sampling system to contain nuclear contamination. No handlemeter supplied.

TDA-2ENL (See Note 2)
Standard TDA-2EN with direct reading logarithmic scale.

OPTIONS

Digital Readout—
Digital readout with floating decimal, gives readout to .001.

Log Scale—
A direct reading log scale is available.

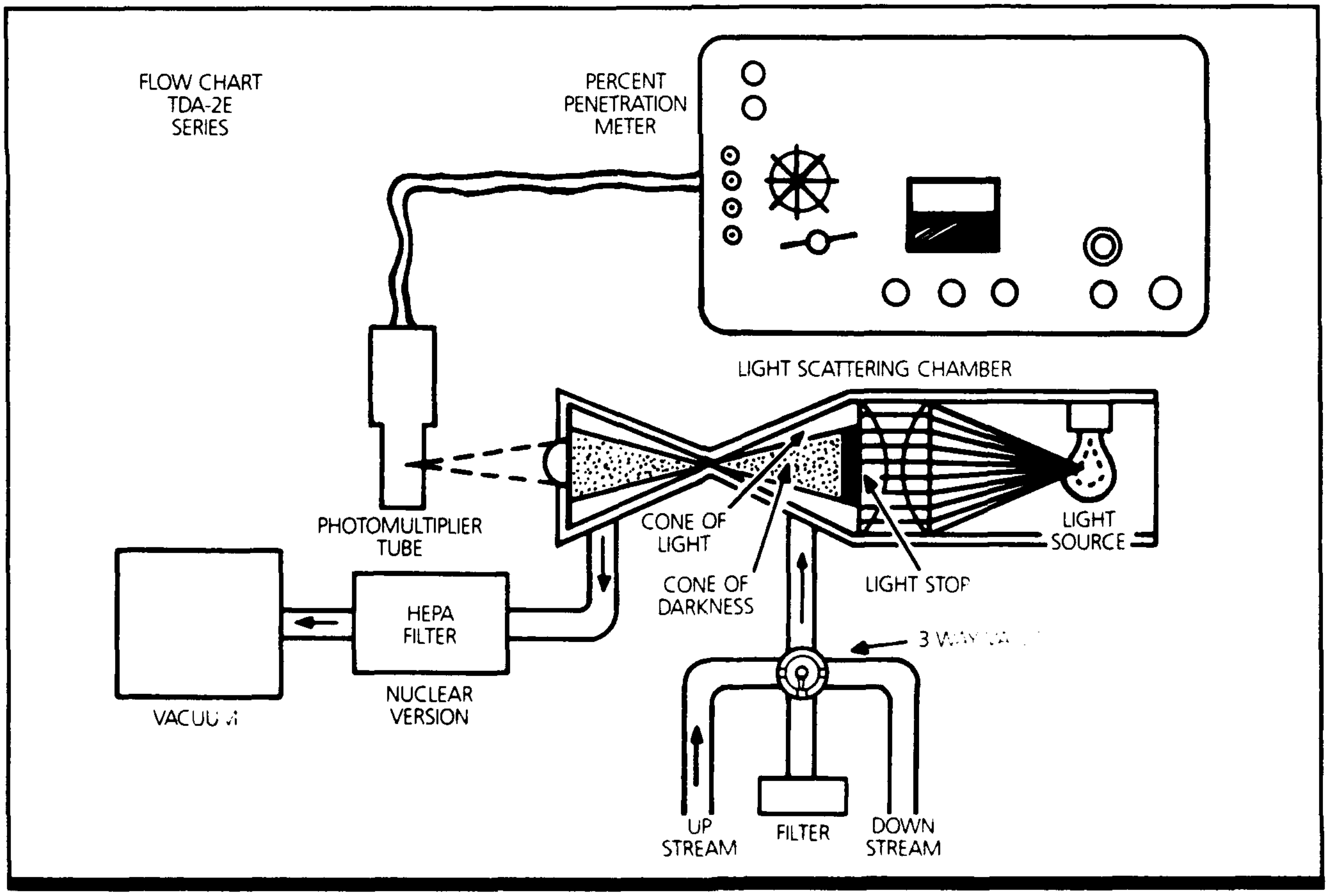
Handlemeter Extension—
Equipped with tubing to read remotely up to 100 feet from instrument.

Spare Parts Kit—
Spares for light source, phototube, fuses, vacuum pump repair kit, internal filter and integrated circuit.

Note 1: Uses TDA-2E-S Spare Parts Kit
Note 2: Uses TDA-2EN-S Spare Parts Kit

...PLICABLE STANDARDS AND SPECIFICATIONS

U.S. Federal Standard 209b, paragraph 50.
American Association of Contamination Control standards CS-1T, CS-2T and CS-6T.
American National Standards Institute N101.1-1972.
ANSI/ ASME N510-1980.
National Sanitation Foundation No. 49.
Institute of Environmental Sciences IES-RP-CC-001-86
Institute of Environmental Sciences IES-RP-CC-002-86



APPENDIX K

AIR TECHNIQUES
DIVISION OF HAMILTON ASSOCIATES INC
1716 WHITEHEAD ROAD
BALTIMORE, MARYLAND 21207
TELEPHONE (301) 944-6037
FAX (301) 298 3919

AT-003A-1 5M-0290

PRINTED IN U.S.A

TDA®-2ENB Respirator Leakage Tester

The TDA-2ENB Respirator Leakage Tester is a completely self-contained apparatus allowing the user to test all half and full face respirators for leakage in compliance with NUREG 0041.

This unit incorporates the latest state-of-the-art design, primarily developed for the nuclear industry but also employed by other respirator users. The TDA-2ENB uses a standard TDA-2EN portable photometer as its detection device. The TDA-2EN may be removed from the unit and used to check HEPA filter banks for leakage. This feature gives the TDA-2ENB a great deal of versatility.

The TDA-2ENB operates by drawing a 1 cfm sample of HEPA-filtered air from inside the respirator. An aerosol generation system creates a sub-micron aerosol challenge agent which is sprayed around the respirator. Should a leak be present in the respirator under test, a portion of the aerosol being sprayed around the mask will be drawn into the 1 cfm sample and through the forward light scattering photometer indicating a leak.

Another feature of the TDA-2ENB permits the operator to inflate a peripheral seal to effect a positive seal between the full face mask and the full face head form.

ATI
AIR TECHNIQUES INCORPORATED
1801 WHITEHEAD ROAD
BALTIMORE, MARYLAND 21207
TELEPHONE (301) 944-6037

TDA®-2ENB Respirator Leakage Tester

PURPOSE
To test full and half mask respirators for leakage through lenses, valves, etc., with a submicron aerosol utilizing a portable, nuclear-type, aerosol photometer

APPROXIMATE DIMENSIONS
Width: 4 feet
Height: 3 feet
Depth: 2 feet

CONSTRUCTION
Standard heavy-duty work bench with Nevamar-covered work surface

MAIN COMPONENTS
TDA-2EN Portable Aerosol Photometer

Full face test head form with inflatable peripheral seal

One-half mask test form, if required, with small, medium and large templates

Aerosol generation system

Control console for peripheral seal

Work bench

UTILITIES
Clean, dry, compressed air at 50 psi and 2.5 cfm (actual rate)

115 volt, 60 hz electricity (5 ampere capability)

FACILITIES
Well-lighted area (approximately 4' × 6')

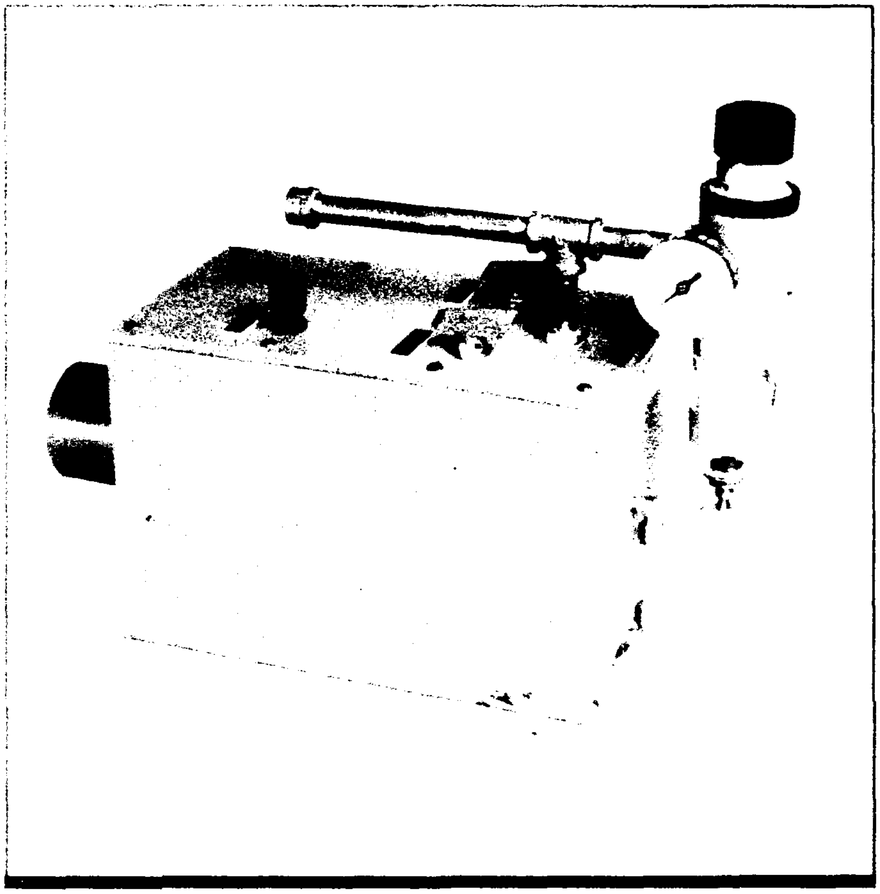
A ventilation hood is suggested to prevent aerosol escape into area (approximately 2' × 4'), suspended over test station with an air flow from 100 to 300 cfm

APPLICABLE STANDARDS AND SPECIFICATIONS
NUREG 0041
30 CFR 11

AIR TECHNIQUES INCORPORATED
1801 WHITEHEAD ROAD
BALTIMORE, MARYLAND 21207
TELEPHONE (301) 944-6037

TDA®-4A Aerosol Generator

The TDA-4A Aerosol Generator is used to detect leaks in air filtration systems. It is simple and easy to operate requiring only liquid aerosol and clean, compressed air. Based on the Laskin nozzle type apparatus, it creates a liquid aerosol of consistent particle size distribution by shearing the liquid with air. Used in conjunction with the TDA Particulate Detection Units, it will quickly and efficiently test clean benches, filter banks, clean rooms and filter units for leaks. The controls allow fractions of the entire aerosol output to be used to compensate for different conditions. When the entire output is diluted by 1,000 cfm of air, the aerosol concentration is approximately 100 micrograms per liter. With both valves closed, one nozzle is in operation and combinations of three, six, and eight nozzles may be obtained by opening or closing the two valves. With increased sensitivity of the detection units it is possible to test for leaks in filter banks up to 4,000 cfm, but the operator is cautioned that a test performed in this fashion will be done at less than 100 micrograms per liter aerosol concentration.



APPLICATIONS

This equipment is applicable for industrial, medical, pharmaceutical and other types of contamination control installations . . . for monitoring, controlling, or leak testing the following:

- **Filters**—any size or efficiency . . . especially for pinhole leaks at lower than rated flow for high efficiency units.

- **Work Stations**—any work station using filters . . . for leaks around seals, gaskets, filter holders, and any other possible sources of leaks.

- **Clean Rooms**—filter systems of laminar or non-laminar rooms, tunnels, or similar units . . . for leaks around seals, gaskets, or filter frames.

- **Filter Banks**—filter systems of laminar or non-laminar flows, for influent or effluent air handling . . . for leaks around seals, gaskets, or filter frames.

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APPENDIX K

TDA®-4A Aerosol Generator

CONSTRUCTION
Aluminum

SIZE
12" × 7" × 8"

WEIGHT
15 lbs.

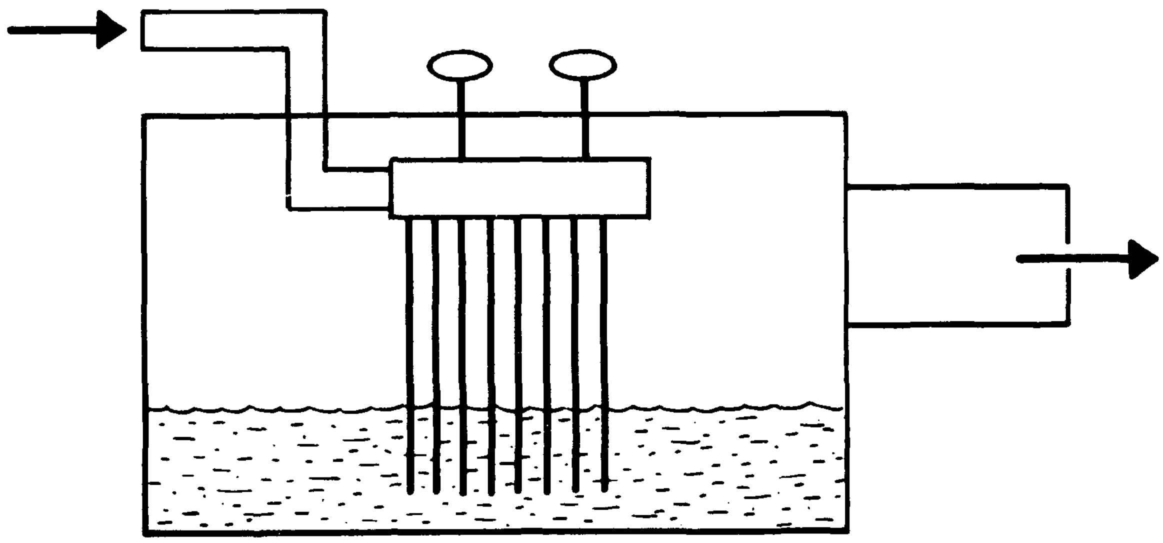
PARTICLE SIZE DISTRIBUTION
99% + less than 3.0 micron
95% less than 1.5 micron
92% less than 1.0 micron
50% less than 0.72 micron
25% less than 0.45 micron
10% less than 0.35 micron

OPERATING TEMPERATURE
Ambient

CAPACITY
Up to 4,000 cfm Systems

UTILITIES
24 cfm clean air at 20 psi

APPLICABLE SPECIFICATIONS AND STANDARDS
U.S. Federal Standard 209b, paragraph 50.
American Association of Contamination Control standards CS-1T, CS-2T and CS-6T.
American National Standards Institute N101.1-1972.
ANSI/ ASME N510-1980.
National Sanitation Foundation No. 49.
Institute of Environmental Sciences IES-RP-CC-001-86
Institute of Environmental Sciences IES-RP-CC-002-86



FLOW CHART

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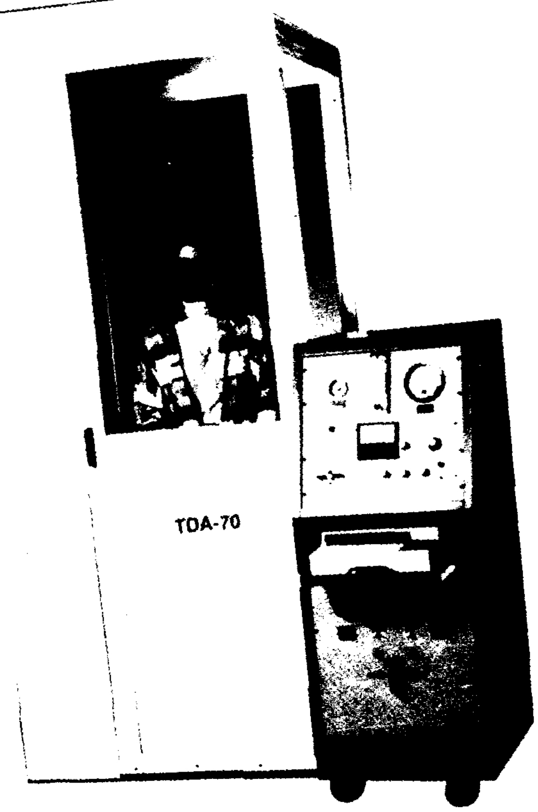
TDA®-50 Aerosol Tester

For quantitatively evaluating the fit of respirator and gas mask face pieces while being worn by the user

Housed in a Modular Roll-Around Type Cabinet



THE TDA-50 QNFT FACE FIT TESTER CONSISTS OF THE FOLLOWING COMPONENTS:

1. A metal cabinet which is caster-mounted containing the electronics and aerosol generating components.
   - The photometer is of the forward light scattering type, solid state, OP-AMP.
   - All controls are on the front of the cabinet.
   - Connections to the test chamber are on the side of the cabinet.
   - The aerosol generator is of the single laskin nozzle type.
   - An optional strip chart recorder mounted on a slide-out drawer is included in the cabinet and is supplementary to the direct reading percent penetrometer.
   - The detection system reads out linearly in percent of penetration from 100 to 0.0001 percent.
   - Unit is specifically designed to be used with corn oil.
2. The test chamber has four extra large windows to allow the operator to view all exercises and eliminate any claustrophobic effects. A large, 28" × 90", door is featured for easy entry and exit. The internal dimensions are 40" × 40" × 90".

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TDA®-50 Aerosol Tester

The TDA-50 Aerosol Face Fit System is an instrument utilizing the latest developments in forward light scattering photometry with a controlled aerosol for a test agent. It is used to evaluate the fit of respirator and gas mask facepieces while being worn by the user. Since the aerosol generated by the TDA-50 is non-toxic (details available on request) the system is an excellent aid for obtaining necessary data on facepiece fit.

The TDA-50 consists of two separate systems – one generates the challenge aerosol and the other measures the aerosol concentration and detects the percentage of leakage, if any, in the facepiece. The generator is of the Laskin nozzle type, conforming to Model III as shown in NRL Report 5929. The aerosol produced has an approximate light scattering mean geometric diameter of 0.70 microns and ranges from 0.3 to 3 microns. Measured distribution approximates:

99% + less than 3 micron
95% less than 1.5 micron
92% less than 1.0 micron
50% less than 0.72 micron
25% less than 0.45 micron
10% less than 0.35 micron

The product of the generator is diluted with filtered air so that a concentration range from 10$\mu g/l$ to 100$\mu g/l$ may be obtained. The aerosol is mixed thoroughly by a riffle system of baffles in the mixing chamber before being passed into the test chamber.

The detection system is based on the latest of the TDA series of forward light scattering photometers. It determines the concentration of aerosol, and using this as a base line, reads out linearly the percent of penetration of the facepiece down to 0.001%. The photometer is available in meter or digital readout. With the meter, standard readings are to .001 but .0001 is available as an option. With digital readout the same sensitivity is available.

The entire apparatus is housed in an attractive modular cabinet of the roll-around type. Specifications and features are:

SIZE
21"W x 26"D × 52½"

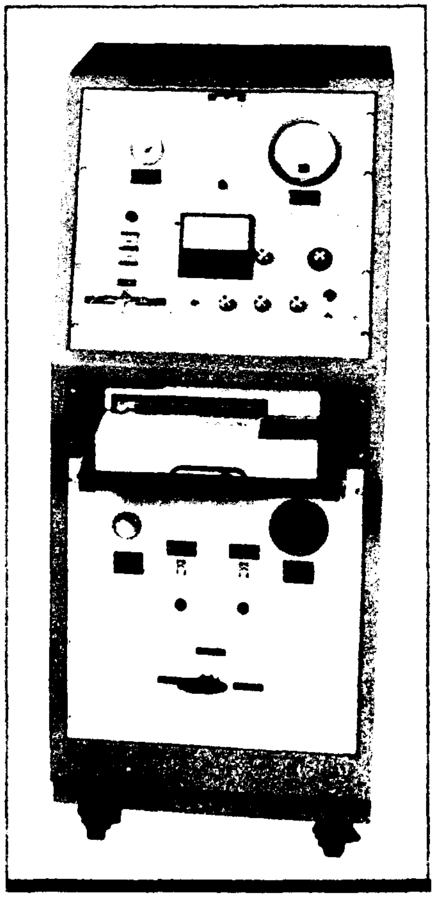
WEIGHT
250 lbs.

REQUIRED UTILITIES
110 VAC (other on request)
Plant air if desired

COMPRESSOR
Continuous duty, oil-less

VACUUM PUMP
Continuous duty, oil-less

SENSITIVITY
Reads to 0.0001%



APPLICABLE SPECIFICATIONS AND STANDARDS
ANSI Z88.2 and Z88.10
U.S. Army Respiratory Protection Program TB 502
OSHA 29 CFR 1910.134
NUREG 0041

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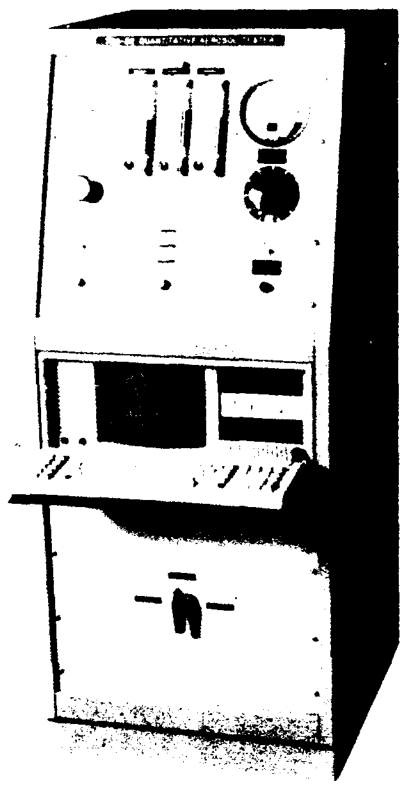
TDA®-52 Dual Computerized Quantitative Respirator Fit Tester

Air Techniques proudly offers computerized Respirator Facefit Testing. We've added an IBM compatible PC to our industry standard quantitative fit tester, Model TDA-52, to offer you state-of-the-art respirator fit testing.



FEATURES

- Standardization of fit test procedure eliminates operator error and need for extensive training time. Computer integration of area below the peaks provides automatic mean fit factor.
- Test two people simultaneously with one operator.
- Test aerosol concentration automatically maintained to allow for nonstop testing.
- Hard copy printout generated for *each* test shows pertinent test subject data as well as fit factor peaks per exercise.
- Computerized diagnostic instrument check eliminates time-consuming troubleshooting.
- Direct software feed to main frame available.
- Computer-controlled "Quick-Start" readies system in 10 minutes from cold start.
- Automatic upstream and downstream sampling is computer-controlled to minimize detector oil build-up and avoid frequent cleaning.
- Featuring an IBM-Compatible PC which incorporates a 9" screen, 5¼" floppy disk drive and a 20 megabyte hard disk drive.
- High Quality Printer with an 8½" × 11" permanent fit test report.
- Master fit test software program.
- Diagnostic self-check software program.
- Automatic aerosol sampling of test subject #1, #2 and test aerosol concentration.
- Two-way intercom system for test chamber hook-up.
- Front panel designed for single operator control of simultaneous fit tests.
- Test program software designed so operator may change test exercises and duration.
- Automatic zero baseline.
- Automatic range select throughout test.
- Exclusive design airjet generator features "hard-coat" compatibility with corn oil aerosol.
- Generator snaps apart for quick and easy cleaning.

CHAMBER FEATURES

- Nine easily-handled, windowed panels slide into the groove of the panel and door sections to make an air tight seal.
- One-piece matching ceiling section screws down on to top edge of side panels.
- Large 28" × 90" doors allow for easy entrance and exit.
- Threshold of inner door is flush-mounted to eliminate tripping.

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TDA®-52 and TDA®-72 Combination

CHAMBER FEATURES (Cont.)

- Return aerosol HEPA filter mounted externally for instant change-out.
- Door handles mounted inside chamber for test subjects.
- Non-locking door controlled by heavy-duty hydraulic door closer.
- Non-slip floor grids.
- Ceiling and floor aerosol plenum panels designed for removal and white interior coating of chamber further facilitates easy cleaning of any oil build-up.
- Six extra large windows in inner portion of chamber allow operator to view all exercises and eliminate claustrophobic effect.
- Large 47" × 30" airlock section also has extra large windows.
- Modular construction is designed for easy transport to test facility and may be hand-carried through standard door openings for assembly in 8' ceiling rooms.
- Intercom speaker mounted inside.
- Sample line ports and aerosol hook-ups installed on both sides of chamber.
- Exclusive aerosol Intro/Exhaust system and weather stripping seal minimize any aerosol leakage.
- Outside chamber dimensions are 92" high × 48" wide × 96" long.
- Interior chamber dimensions are 88" high × 47" wide × 65" long to accommodate comfortably two test subjects through a wide range of exercises.
- Airlock chamber dimensions are 88" high × 30" deep × 47" wide with offset door openings which allow unrestricted entry and exit.

SPECIFICATIONS

- Auto-Sample/Auto-Zero/Auto Quick Check/Auto Quick Start
- 5 1/4" Floppy Disk or Hard Disk Data Storage
- Fit Test Program Software
- Diagnostic Test Program Software
- Power: 120 vac, 50/60 Hz.
- Particle Size (MMAD): 0.45 micron
- Aerosol Concentration: 25 ± 5 mg/m³ automatically monitored.
- Amplifier: Solid-State, Linear.
- Dynamic Range: 100% to 0.001%.
- Sensitivity: Calculated fit factors up to 100,000.
- Detector: Exclusive Op-Amp—three ATI light scattering detectors.
- Test Sample Rate: 1-5 lpm.
- Castorized "E-Z Roll" Cabinet
- Dimensions: 26" deep × 22" wide × 52" high.
- Weight: 325 lbs.

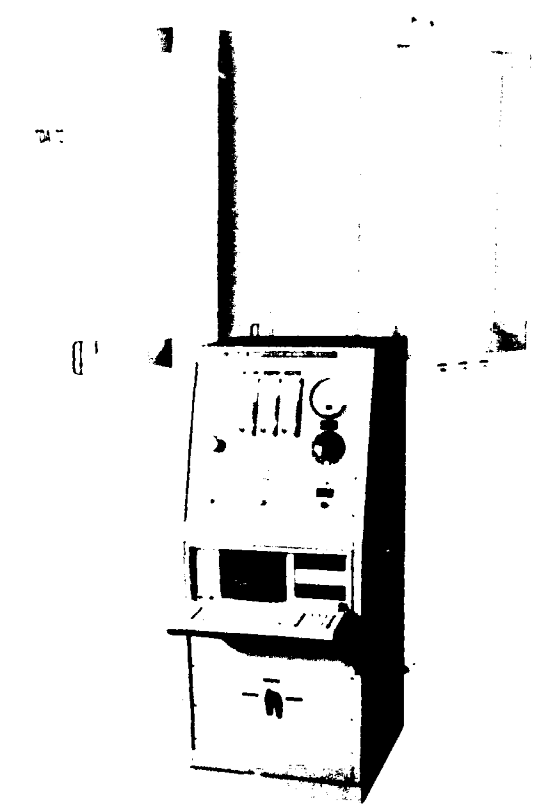
APPLICABLE STANDARDS AND SPECIFICATIONS

ANSI Z88.2 and Z88.10.
U.S. Army Respiratory Protection Program TB 502.
OSHA 29 CFR 1910.134.
NUREG 0041 NIOSH 76-189.

TDA®-71 Option

SINGLE TEST CHAMBER WITH AIR LOCK

This unit incorporates the same features as the TDA-72 except for dimensions as follows:
Outside chamber dimensions are 92" high × 48" wide × 63" long. Interior chamber dimensions are 88" high × 47" wide × 32" deep.



DUAL TEST CHAMBER WITH AIR LOCK

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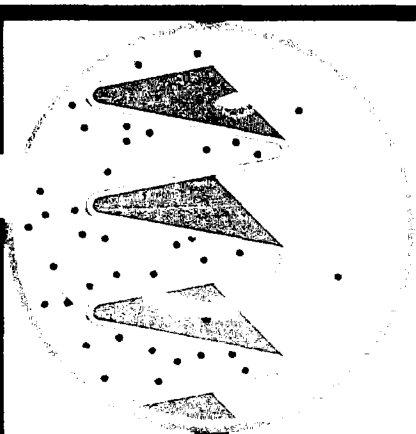


Model 8140 Automated Filter Tester

Features and Specifications

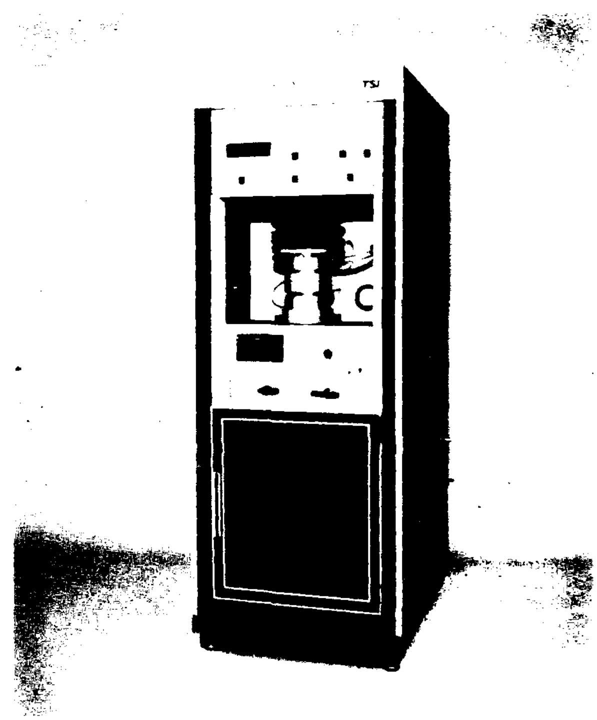
TSI's Model 8140 Automated Filter Tester represents a new generation of production filter testers. The TSI tester is faster and easier to operate than presently available production filter testers and requires little operator training. It measures efficiencies of 99.9999% in less than 15 seconds and can measure higher efficiencies with extended test times. Aerosol detection is accomplished with condensation nucleus counting technology for top-notch accuracy over a wide dynamic range.

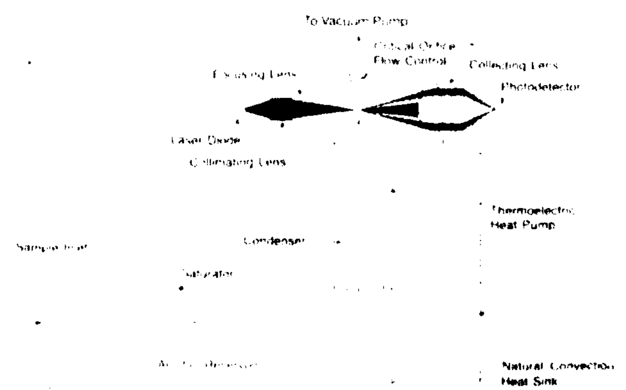
The tester generates an aerosol which is used to challenge a test filter. Particles are counted both upstream and downstream of the filter, with filter penetration calculated by a microprocessor. To conduct a test, the operator simply puts a filter in the filter holder which is then pneumatically closed. The test then runs automatically, with the penetration, flow rate and pressure drop displayed at the end of the test.

A microprocessor-based tester, the Model 8140 has a self-diagnostic feature which significantly reduces operator training and the need for operator intervention during the test sequence. If any parameter is outside the specified range, the microprocessor alerts and directs the operator to the source of the problem.

Two condensation nucleus counters (CNCs) make the system highly reliable. A CNC enlarges submicrometer particles by condensing alcohol around the particles until they are large enough to be detected using a light-scattering technique.

The tester can be used with DOP or other materials as the challenge aerosol.





The Model 8140 detects particles upstream and downstream of a filter using two condensation nucleus counters

Features

- Fast, reliable filter efficiency measurements
- Automated operation with minimum operator training
- Extremely accurate concentration measurements over a wide dynamic range
- Measures efficiencies up to 99.999999%
- Filter pressure drop and flow rate measurements
- Self-check diagnostics
- Easy accessibility in movable cabinet
- No zero and span adjustments on detector
- Printer provides hard copy output
- RS-232 data output

Options

- Filter pass/fail indication available
- Remote control of tester

Specifications

Challenge Aerosol Generation

Technique .... Atomizer

Oil Generator (using DOP)
- **Diameter** .... 0.18 micrometer
- **Geometric Standard Deviation** 1.6
- **Number Concentration** .... 1,000,000 particles/cm^3

Salt Generator (using NaCl)
- **Diameter** .... 0.1 micrometer
- **Geometric Standard Deviation** 1.9
- **Number Concentration** .... 1,000,000 particles/cm^3

Challenge Aerosol Detection
- **Technique** .... Condensation Nucleus Counter
- **Sample Rates** .... 23.3 cm^3/sec
- **Dynamic Range** .... <0.01 to 10^6 particles/cm^3*

Flow Measurement
- **Technique** .... Orifice with electronic pressure transducer
- **Accuracy** .... ±3% of reading
- **Range** .... 15 to 100 l/min

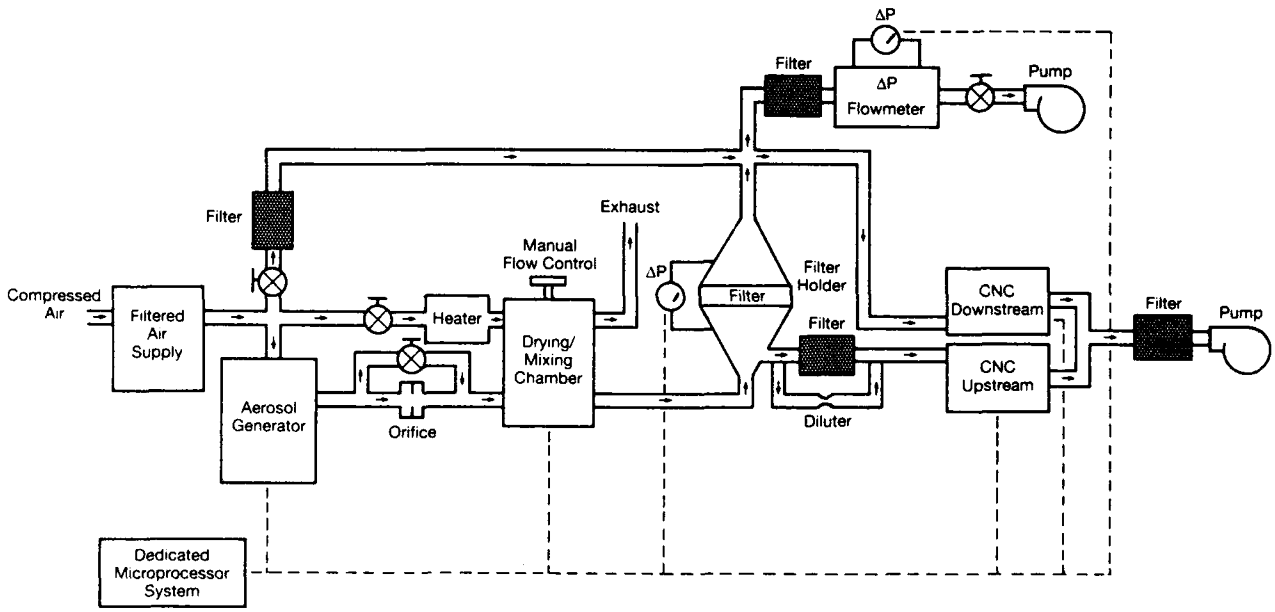
Pressure Measurement
- **Technique** .... Electronic pressure transducer
- **Accuracy** .... ±0.5% F.S.
- **Range** .... 0 to 150 mm H_2O or 0 to 1000 mm H_2O

Efficiency Measurements
- **Flow Rate through Media** .... Selectable from 15 to 100 l/min
- **Operating Range** .... Efficiencies up to 99.999999%
- **Automation and Data Management** .... Dedicated microprocessor

Operational Requirements
- **Power** .... 115 VAC, 60 cycle, 10A or 230 VAC, 50 cycle, 5A
- **Compressed Air** .... 14 scfm @ 60 psi

Physical Characteristics
- **Size** .... 65 in. H x 19 in. W x 30 in. D (165 cm x 48 cm x 76 cm)
- **Weight** .... 400 lbs (180 kg)

*with 100:1 diluter **Specifications are subject to change without notice.**



TSI.

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Model 8160 Automated Filter Tester

Features and Specifications

TSI Model 8160 Automated Filter Tester is the most advanced automated tester available for challenging high-efficiency air filters with submicrometer aerosol. The Model 8160 employs two exclusive TSI technologies:

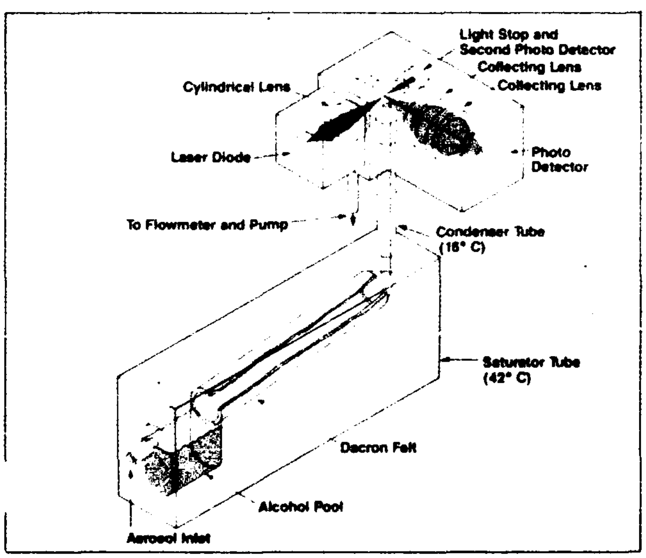
- Electrostatic classification for generating monodisperse, submicrometer aerosol in either solid or liquid form
- High-resolution submicrometer particle detection using a Condensation Nucleus Counter

With monodisperse generation, the Model 8160 can measure filter penetration as a function of particle size, or filter penetration as a function of flow rate. It can determine the particle size exhibiting the highest penetration.

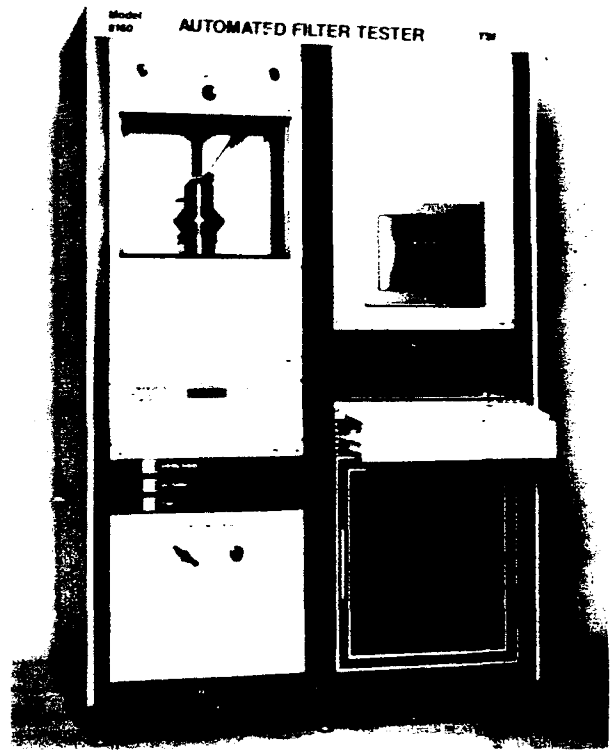
Monodisperse aerosol is produced using the TSI Electrostatic Classifier, which selectively strips out a narrow particle size range from a polydisperse aerosol generated within the system.

TSI Condensation Nucleus Counter (CNC) detects aerosol particles using a single-particle counting technique for concentrations below 10^4 particles/cm^3 and a photometric technique for concentrations up to 10^7 particles/cm^3. The CNC uses a highly stable, laser diode light source and offers a large dynamic range, allowing measurements of filter and single-sheet media efficiencies to 99.999999%.

All tester operations are automated using a microcomputer. Data is presented in tabular and graphic form.



The Model 8160 detects particles using a TSI Condensation Nucleus Counter.



Features

- Produces monodisperse challenge aerosol using a TSI Electrostatic Classifier
- Extremely accurate particle concentration measurements over a wide dynamic range
- Filter pressure drop and flow rate measurements
- Measures efficiency versus particle size and also efficiency versus flow rate
- Fast, reliable filter efficiency measurements
- Automated for easy operation
- Data analysis using a microcomputer system
- Measures efficiencies to 99.999999%
- Easy accessibility in movable cabinet
- No dilution required

Specifications

Challenge Aerosol Generation

Technique	Constant Output Atomizer and Electrostatic Classifier
Size Range	Selectable from 0.05 μm to 0.4 μm, monodisperse (0.01 μm to 0.4 μm optional)
Geometric Standard Deviation	<1.1

Challenge Aerosol Detection

Technique	Condensation Nucleus Counter
Sample Rate	5 cm^3/sec.
Sensitivity	<0.01 to 10^7 particles/cm^3
Accuracy	±10% of reading

Flow Measurement

Technique	Thermal mass flow meter
Accuracy	±2% of reading, ±0.2% F.S.
Range	1.5 to 150 liters/min

Pressure Measurement

Technique	Solid state pressure transducer
Range	0 to 10 cm H_2O or 0 to 100 cm H_2O (other ranges also available)
Accuracy	±0.3% of reading

Efficiency Measurement

Flow Rate through Media	Selectable from 5 to 90 liters/min
Operating Range	Efficiencies to 99.999999%
Automation and Data Management	IBM microcomputer system

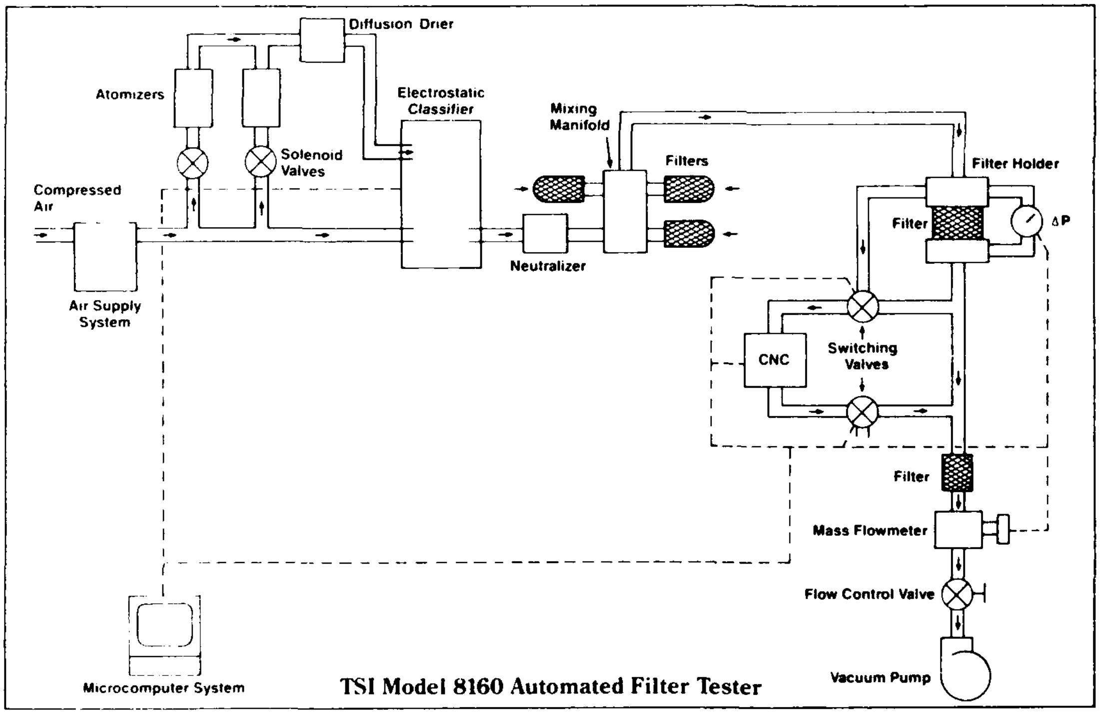
Operation Requirements

Power	115VAC, 60 cycle, 10A or 230VAC, 50 cycle, 5A
Air	4 cfm @ 80 psi.

Physical Characteristics

Size	72 in. H x 48 in. W x 32 in. D (183 cm x 122 cm x 81 cm)
Weight	900 lb (410 kg)

Specifications are subject to change without notice.



TSI Model 8160 Automated Filter Tester

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